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Papers on Hydraulic Engineering. By SAMUEL MCELROY, C. E.

(Continued from page 225.)

No. 4.—CITY SEWERAGE.

Analysis of Sewage.—In proper connexion with the disposal of city sewage, the question of its nature in passing through the outlets becomes important.

An analysis of four prominent London sewers in the report of 1857, p. 8, gives the following result in grains of solid matter per gallon (Imperial), taken from the mouths of the sewers:

Constituents.	Earl.	Falcon Brook.	King's Scholars' Pond.	Total.
Organic, . .	2·738	3·987	17·75	16·117
Mineral, . .	46·110	40·146	47·23	51·304
Total, . . .	48·848	44·133	64·98	67·421

As compared with six samples of Thames water, having an average of 2·059 grains organic and 23·281 grains mineral contents, the similarity is remarkable.

Another analysis of sewage flow, under the intermittent system of supply in London, where the water is let on three times a week, is as follows, in grains per gallon:

Constituents.	Ordinary Water Days.	Extra Water Days.
Soluble matter, ...	127	96
Insoluble "	40	28
Total, ...	167	124

An analysis of two sewers given by Prof. Way, in the Report of 1850, App. 3, p. 136, makes the following subdivision of constituents:

Constituents.	Dorset Square.			Barrett's Court.		
	Soluble.	Insoluble.	Total.	Soluble.	Insoluble.	Total.
Organic Matter and Salts of Ammonia, .	57·32	23·00	80·32	121·50	180·32	301·82
Street Sand and Detritus,	0·78	44·50	45·28	1·39	19·30	20·69
Soluble Silica, .	1·16	12·09	13·25	1·57	10·94	12·51
Phosphoric Acid, .	2·53	1·64	4·17	7·71	2·73	10·44
Sulphuric " .	0·28	3·63	3·91	10·71	4·02	14·73
Carbonic " .	10·58	1·99	12·57	11·62	3·97	15·59
Lime, . . .	7·40	8·37	15·77	7·50	17·03	24·53
Magnesia, . .	·07	Traces.	·07	2·87	Traces.	2·87
Peroxide of Iron and Alumina, .	Traces.	2·66	2·66	Traces.	6·20	6·20
Potash, . . .	2·60	0·72	3·32	46·91	1·22	48·13
Soda, . . .	. . .	. . .	. . .	None.	1·51	1·51
Chloride of Sodium,	27·27	2·10	29.37	31·52	1·72	33·24
	109·00	100·70	209·70	243·30	248·96	492·26

An analysis of Edinburgh sewer water gave 62 grains in solution and 244 of solid matter in suspension.

It is stated in the Report for 1850, that—

"In thoroughfares of considerable traffic in large towns, as in the main streets of the Metropolis, as much ordure is dropped on the surface of the highways as is deposited in the cesspools of the corresponding houses. Thus it is reported that the quantity of dung removed daily from a space of 68 acres of paved roadway surface, including the bye-streets of little traffic, as well as the crowded streets of the city of London, varied from 505 to 596 loads per week, or was on the average 92½ loads per day, nearly all of horse dung."

Samples of water taken from the street gullies, during a rain, gave, for ten specimens, an average of 113·34 grains of soluble and 149·25 grains of insoluble matter per gallon. There is, however, considerable difference between the samples, ranging from 44 to 276 grains soluble and 3 to 590 grains insoluble matter.

In these analyses there are considerable differences in results, which may be accounted for by relative completeness of sewer action, and

relative stages of water supply, to a certain extent. The enormous Fleet sewer, 18·5 feet high by 12 feet width at its mouth, does not operate uniformly, being a collector of deposit, rather than an outlet of ordinary sewage. Hence, an analysis, at its outlet, or in other sewers of its class, may not, even in storm floods, show a correct proportion of solid matter. As given, with that of several other sewers and systems of sewers, we have the singular conclusion that the city sewers are actually discharging purer water than the wells, which have been, and are even now, in general use in many of our cities. There are wells now in use, in Brooklyn and other places, kept up at the city expense, which contain more grains of solid matter per gallon, than the sewage flow of populous cities, in some cases, as here demonstrated.

The general conclusion to be drawn from this examination, and from the practical working of properly devised and constructed sewers, in such examples as the 227 cases illustrated in the London Report of 1855, and the experience of other European cities, and of Brooklyn, is this:—that the popular idea of difficult flow in sewage is entirely erroneous, and that the excessive proportions of city sewers in common use, are in no respect warranted by the laws of their daily operation.

Not only is it true then that all the soluble matters of sewage are readily taken up and carried off, as well as all matter held in suspension, by the large surplus of water, which of necessity enters the sewers, but it is also a matter of demonstration, that insoluble materials of considerable weight, are readily moved by the ordinary force of the sewer currents.

Experiments, given by Mr. Blackwell, in the Report of 1857, p. 168, App., on brick-bats, building stone, chalk, flints, coal, clinkers, copper slag, limestone, oyster shells, slates, nails, scraps of iron, gravel, and other materials, show that they were started from rest, with a current of 1·75 to 2·5 feet per second, and moved at rates from 1·25 to 2 feet per second, by currents from 4 to 4·25 feet, the latter being common velocities for pipes with gradients as low as 1 in 60.

Value of Sewerage.—In the promotion of vegetation, the nitrogen, in the form of ammonia, with the subordinate properties of alkalies, phosphates, and sulphates, contained in manure, give it its agricultural value, and among manures, one of the best in quality, comes from a prominent constituent of house sewage. Eminent chemists have shown experimentally, that the nitrogen annually produced by one man, at 16·41 pounds, is sufficient for the supply of 800 lbs. of wheat, rye, or oats, or of 900 lbs. of barley, and it is estimated that each person in a community is worth, in this view, two pounds of bread per day.

The sewer discharge of the city of Milan, is artificially thrown over a large extent of meadow land, some of which, on this account, yields a net revenue of 40 dollars per acre.

By the same process in use at Edinburgh, lands formerly renting from 10 to 30 dollars per acre, now bring 150 to 200 dollars, 25 dollars per acre being estimated as the value of sewage water. It is also

estimated there, that 560 pounds of dissolved and suspended matter contained in 17,920 gallons of sewage, are equal in fertilizing power to 280 lbs. of guano or 15 tons of farm yard manure, while the relative cost of application, and the material is as $3·18 to $5 and to $15. About 150 acres are thus manured.

Experiments at Clitheroe, Lancashire, with 8 tons of sewage water on one acre, and 15 tons ordinary manure on another, gave a produce of 1·875 to 1, in favor of the former, as to quantities, and 1·875 to ·532 as to weights.

The following analysis of human excrement is given by Mr. Laws, p. 392, App. London Report, 1857.

Pounds per head per annum; average for both sexes and for all ages:—

Mineral matter,	10·34 lbs.
Carbon,	16·85 "
Nitrogen,	7·94 "
Nitrogen ammonia,	9·64 "
Phosphates,	4·58 "
Total dry substance,	49·95 lbs.

Assuming that these constituents could be separated in a pure and dry state, the estimate of value is £15 per ton, or for 48 persons, 6 shillings per head. At this rate London produces 51·635 tons, worth £774·525 or $3,872,625.

The fluid discharge is estimated at 2·5 lbs. per day, or 912 lbs. per year, per head.

The estimated value, based on an analysis of Prof. Way, previously given for 209·70 grains solid matter per gallon, as stated, p. 11. App. Report of 1857, for 100 tons of the solid constituents of the mean flow of London sewage, is as follows:—

		£.	s.	d.
7·982	tons ammonia at £56,	446	19	10
1·269	" insoluble phosphate of lime at £7	8	17	8
2·631	" soluble " " at £32	84	3	10
1·	" potash at £31	31	0	0
30·110	" organic matter at £1	30	2	2
57·008	" no value,	00	0	0
100·000	tons,	£601	3	6

It was farther determined that "at least sixth-sevenths of the constituents of sewage valuable for agricultural purposes, exist in the soluble portion, the suspended matter having a comparatively small value."

The value deduced for 100 tons of sewage (220 galls. per ton) is—

	lbs.	£	s.	d.
Suspended matter,	82·72	0	2	2½
Dissolved "	245·95	0	15	4½
	328·67	0	17	7

Applying this value to the sewage of New York, on the consumption of 1861, about 44,000,000 gallons, or about 2,000,000 tons sew-

age per day, at 4·39 cents, for 365 days, would amount to $3,204,700 per year.

The city of Paris provides for the systematic removal of cesspool contents to the *Voirie* of Montfaucon; and the estimate of cost in 1850, for the removal of 230,000 cubic metres was $414,000. The income from the poudrette manufactured is not given for that year, but in 1843 was $105,000. It probably fell short, considerably, of the expense of removal. 80 to 90 per cent. loss is estimated for removal.

French chemists give the following comparative value of manures, as applicable to equal effects on one *hectare* (2·5 acres) of land —

	Kilogrammes.
Good farm dung,	10,000
Human Urine, unfermented,	5,600
Poudrette of Montfaucon,	2,550
Mixed Human Excrements,	1,333
Liquid Blood of the *Abattoirs*,	1,333
Bones,	650
Guano (average),	512
Human Urine, in fermentation and incompletely dried,	233

Sufficient evidence is adduced here of the intrinsic value of sewage matter, although in somewhat detached and contradictory form, as affected by local conditions and treatment; and there is force and wisdom in the language of Victor Hugo on this subject:—

"All the human and animal manure which the world loses, if returned to the land instead of being thrown into the sea, would suffice to nourish the world. Do you know what those piles of ordure are, collected at the corners of streets, those carts of mud carried off at night from the streets, the frightful barrels of the night-man, and the feted streams of subterranean mud which the pavement conceals from you? All this is a flowering field, it is green grass, it is mint, and thyme, and sage, it is game, it is cattle, it is the satisfied lowing of heavy kine at night, it is perfumed hay, it is gilded wheat, it is bread on your table, it is warm blood in your veins, it is health, it is joy, it is life. * * * * Statistics have calculated that France alone pours into the Atlantic a sum of half a million. Note this: with these five hundred millions one-quarter of the expenses of the budget would be paid. The cleverness of man is so great that he prefers to get rid of these five hundred millions in the gutter. The very substance of the people is borne away, here drop by drop, and there in streams, by the wretched vomiting of our sewers into the rivers and the gigantic vomiting of our rivers into the ocean. Each eructation of our drains costs us one thousand francs, and this has two results; the earth impoverished and the water poisoned; hunger issuing from the furrow and illness from the river."

Utilization.—It often happens in the engineering world, that the step from correct theory to complete practice, is almost impossible, from intervening mechanical difficulties. In machinery, the rotary engine is a case in point, and there are various other illustrations of the hindrances which may arise between an educational conclusion and a successful manipulation.

While it is plain, then, from the facts above presented, that the fertilizing value of sewage in large cities is represented by millions of dollars, and is daily thrown away, the same facts show the obstacles which are involved through the very combination of sewage flow, and prevent an economical and convenient separation of the constituent manures.

The analyses of sewage water, show different proportions of solid matter, in some cases less than 1 to 1000, in others 1 to 420, 1 to 330, and 1 to 142. Advocates of utilization have assumed the proportion as 1 to 600, from observations given in the Report of 1853.

In the conclusions of value derived from the analysis of Professor Way, which makes the proportion 1 to 330, the solid contents of 100 tons of sewage are about 708 pounds, of which about 43 per cent. or 328·67 pounds is valuable. It farther appears, that of this 43 per cent., but $\frac{1}{4}\frac{1}{3}\frac{8}{0}$, or about one-quarter is classified as of high value, or less than 12 per cent. of the entire reduced solid constituents. To produce 11·81 tons of concentrated manure, requires 100 tons of solid matter, or 31,638 tons of sewage water, or 6,960,360 gallons, and the value is £562 3s. 8d., or $2811 when the process is complete.

It is evident, then, that the enormous dilution of the fertilizing matter in sewage, while it proves its fluent character, also involves the use of most extensive works in grounds, structures and machinery, to effect its reduction to commercial value, except in those isolated cases, as at Milan and Edinburgh, &c., where the ordinary outfall of the sewers can be conveniently and by gravitation distributed over broad plains, without artificial reduction.

And this state of facts explains the failures which have attended the various local attempts hitherto made to concentrate sewage manure, artificially, by precipitation under treatment of milk of lime, and by other apparently simple processes. For the process in use, in a limited operation at Cardiff, it was shown that 50 square miles of area would be needed to reduce the London sewage, and all other processes are embarrassed at once by the vast quantities of useless matter to be moved and disposed of.

The city of Paris, governed as to its street dirt and cesspools under the strict rules of the *Ordonnance* of 1819, which provides for the systematic removal of these products to places of direct application and manipulation, without the embarrassment of the sewer water, also furnishes in the ratio between cost of removal and income, a decisive argument against the economical or remunerative application of sewage, in a diluted state by results when undiluted; and narrows the question down to the relative propriety of her system of distinct separation of sewage matter, and its special transportation, for the sake of its questionable item of income.

In this special argument, however, the cost of transportation, which is formidable to any city, may be laid aside, as a sanitary necessity, and the Parisian system credited with the entire income of its *poudrette* and street dirt, except so far as it is a matter of demonstration that the cost of cartage largely exceeds that of underground disposal, and the process is objectionable in point of sanitary effects.

In the present state of experience on this subject, it may be assumed that sewage manure, to realize its proper value, under ordinary conditions of sewer outfall, must be kept free from dilution, or in other words, must be prevented from entering the sewers; and that the cost of its reduction is not, up to the present time, justified by the

prospects of income. This is the conclusion of scientific men, after much experimental investigation.

There are, however, some subordinate considerations under this head, worthy of special application, while the whole matter offers itself to continued study and trial. Analysis shows the value of the products of public urinals, and chemistry shows that cheap articles, such as gypsum, chloride of calcium, superphosphate of lime, &c., form combinations with urine, free from smell and retentive of its most valuable properties. In stables, hotels, and public urinals, it is therefore a very simple matter to correct a present common nuisance, and at the same time obtain a valuable manure with small cost, by any adequate arrangement for such combination, which will readily suggest itself for each locality. The luxurious style of our present hotel life, requires this addition to the comfort of the guests, in increased atmospheric purity, and it will pay.

Sanitary Results.—The sewage matter of houses and streets, if dissolved or suspended in cool water, and promptly removed from the city precincts, exerts no injurious effects on the subsoil or the atmosphere; but if the water, which is the proper medium of conveyance, is permitted, from defective sewer action, to deposit the sewage matter under the houses and pavements in the lateral and main sewers, the process of fermentation begins at once to affect the public health. This is true also of the cesspool system in ordinary use, by which decomposition is continually promoted, as an atmospheric effect, and the subsoil contaminated with injurious results to public and private wells and with noxious exhalations.

The great atmospheric deep, pressing over and around a populous town, is prompt to receive and to retain for effect on human health, the evaporations and distillations of the more solid and tangible base. And when we are told "it has been proved scientifically that the atmosphere taken from above a dung heap is purer than that taken from over Paris," we are forcibly reminded of the vast power for evil, treasured up in the hidden depths of every imperfect system of sewerage, and of the injurious influences which are constantly at work. If we add to this a thought of impregnated drinking water, the general warning is complete, and an important key is furnished to the investigation in hand.

The offensive gases, carburetted and sulphuretted hydrogen, miasmata from decaying vegetable and animal substances, and other combinations evolved from collections of sewage matter, are directly obnoxious to public health, in atmospheric effects, which are aggravated or extenuated by various local or special conditions. One portion of sulphuretted hydrogen in 1500 parts of air will kill a kid, one in 800 will kill a dog, one in 250 will kill a horse. It is therefore certain that emanations of this and other kinds in various degrees of combination, must be injurious in proportion to their qualities.

In sparsely settled localities and in certain states of atmospheric change, the ordinary cesspool system, may be deprived of serious effects; but in cities where property is bought and sold by the square

foot, where buildings are erected in dense blocks, carried to great heights and closely peopled, where the streets are narrow and lanes and alleys are common, where the soot, smoke, products of manufactures, and other influences contaminate the atmosphere, and especially in low barometric seasons, the effluvia from the congregated thousands of stagnant cesspools, each a magazine of disease, may well be considered a most objectionable addition to the surcharged air and a fruitful source of malarious diseases.

The medical testimony on this point, in cases directly traced to this special cause, is sufficiently voluminous and conclusive. The contents of a cesspool being used as manure, in school gardens at Clapham in 1830, within six hours every individual was taken with the cholera and two died; at Hastings typhus fever appeared regularly, at the outlet of the town drains, while other parts were free from it; a block of houses in the cloister of Westminster, being the seat of a severe epidemic fever, from fifteen houses 150 loads of night soil were removed, and a new system of sewerage applied, with an immediate change in the atmosphere and an immediate correction in the local mortality; at Antwerp it is observed that though in certain states of the weather no offensive odor could be perceived, yet whenever any fog hung over the city the diffusion of noxious gases was rendered disagreeably sensible, a result common to many other cities; no city regulates its cesspools and street cleaning as rigidly as Paris, yet its atmosphere is said to produce an unpleasant sensation, and the air of its houses is impregnated with emanations from the water closets; the London Fever Hospital, reports for 1851, the receipt of 10 or 12, and in one instance 20 patients, from single houses of a district, where the cesspools were kept in the cellar; in some cities, as at Albany, where sewers have been in part built, the old cesspools are retained, but connected by drains, as overfall outlets, with the street sewer, a process which retains the original evil of accumulation; in other cities, as in Brooklyn, the third in rank in the United States, the subsoil percolation through a gravely foundation was, until recently, relied on for freeing the cesspools, a very large number being still retained in use, since the construction of water-works and sewerage.

The cases of mortality which mark this general system of sewage accumulation and decomposition, might be indefinitely multiplied in evidence, but they all present the same general argument against the entire practice, in following which, mankind is demeaned beneath the example of the animal race in a state of nature.

But the evil of this practice is not confined to miasmatic effects, since the water used for daily consumption and drawn from wells, or left exposed in vessels or cisterns, is impregnated by its powers of absorption from contaminated earth and air. In the lower districts of London, the excess of surface water is thrown upon ground imbued with cesspool matter, which it causes to permeate through the stratum into wells and saturate basement walls and foundations. In one parish closely examined, (Southwark) 48 per cent. of the wells were perceptibly foul or tainted, 82 per cent. of the houses having cesspools,

and 18 per cent. had damp and saturated foundations. Comparing the highest and lowest districts of the city, it appears that in 1838, the deaths from fever were, in one case, 1 in 255 and in the other, 1 in 425; in 1832, the deaths from cholera were 1 in 200 and 1 in 551; and in 1849, 1 in 118 and 1 in 347. Between the highest, the intermediate, and the lowest districts, the ratios in 1849, were 1 in 346, 1 in 256, and 1 in 93. In Albion Terrace, several houses having been depopulated by cholera, it was observed that, among other exciting causes of disease, the cesspools or drains had overflowed into the subterranean cisterns from which the inhabitants derived their supply of water; at Rotherhithe, in 16 houses, supplied from one well, subject to infiltration from an open ditch, 20 cases of cholera occurred; "it stands," we are told, "upon the evidence of common observation, and upon the testimony of the senses of taste and smell, that the waters of the same source and composed of the same chemical constituents, may be largely varied in quality by exposure to different atmospheres, and that impure water taken in the stomach occasionally produces more sudden and violent effects than impure air introduced into the system by the respiratory apparatus;" the analyses of all city wells, compared with the sources of their supply, always show a marked impregnation; many of the wells of London, with over 120 grains solid matter per gallon, are less pure than the sewers which flow past them; New York, long before the introduction of the Croton, was obliged to abandon the use of various wells; in Brooklyn, wells show over 60 grains per gallon, where their supply veins, uncontaminated, contain less than three; these results, which are universal in kind, if not in degree, can have but one explanation, and that is conclusive on this point.

If, to this cesspool and subsoil contamination of the air breathed and the water drank, the system of sewers in use, from imperfect action, becomes a depository of sewage matter, the evil is greatly aggravated, since from beneath houses and streets, finding egress through every vent pipe and gulley, the outer atmosphere and that of the residences, become exposed to flowing currents of noxious gases.

It is as Victor Hugo says; "We might say, that for the last ten centuries, the cloaca has been the misery of Paris, and the sewer is the viciousness which the city has in its blood. * * * * It was said proverbially, *Going into the sewer is entering the tomb*, and all sorts of hideous legends covered this colossal cesspool with terrors. * * * Fagot attributed the malignant fever of 1685 to the great opening of the Marais drain which remained yawning until 1833. The mouth of the drain in the Rue de la Mortellerie, was celebrated for the pestilences which issued from it; with its iron-pointed grating that resembled a row of teeth, it yawned in this fatal street like the throat of a dragon breathing hell on mankind." Experiments with infusoria, fish, and birds, show the fatal character of the sulphuretted hydrogen evolved from decomposing sewage matter, and moisture facilitates the escape of odors, where saturation would tend to repress them. In the Surrey and Kent District, London, (1850,) in one week, about

1000 loads of sewer deposit were removed; a sewer in Earl Street, 5 feet by 3, accumulated 6000 cubic feet of deposit in 31 days from 1200 houses; the London sewers generally show a deposit of 2 feet, and in some cases of 5 feet, and the whole evaporating surface of stagnant and pestilent matter is estimated (1852) as equal to a canal 50 feet wide, 10 miles long, and above 6 feet deep, or an area of 800 acres, 6 inches deep; in collecting specimens of sewer water for analysis (1857) it was observed that heavy rains greatly increased the proportion of solid matter, in one instance from 32·17 grains minimum flow, to 296·97 grains, in storm-flow; the enormous Cloaca Maxima of Rome is nearly filled up, and the Campagna was ruined by the city drains for cultivation or residence; what is true then of Rome, of London, and of Paris, is true of similar cases, all the world over, and the elements of slow disease or swift pestilence, are garnered up most surely, where the very seat of public health and comfort should be firmly established. If a drink of impure water is not followed by a cramp, and a sniff of air "foul enough to knock a man down," fails to do it, the several persons who make up a family, and the families who make a community, following the old customs, fail to trace to the true sources the fatal effects which are common to many families and which sometimes startle entire cities with a sweeping brand of death.

(To be Continued.)

On the Construction of Wrought Iron Lattice Girders.

By Thomas Cargill, C. E.

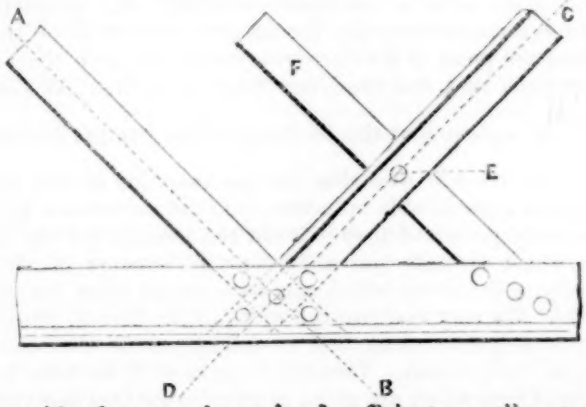
(Continued from page 235.)

From the Lond. Civ. Eng. and Arch. Journal, Sept., 1863.

In the definition of a Lattice Girder, properly so called, given at the commencement of the present subject, it was premised that their must be, even in the smallest specimens, one crossing or intersection, at least, of the ties and struts composing the web of the girder. This condition would suffice of itself, independently of others which have been mentioned, to distinguish the lattice from the pure triangular or Warren form of girder. It is evident from the manner in which the strains on the web are arrived at, that the pure triangular girder, that is, a girder whose web consists of one series of triangles only, without any crossings of the tension or compression bars, is theoretically the foundation of the lattice, as well as of all open-webbed beams. The lattice, however, in its greater inherent stiffness, in its more minute subdivision of strain, in the more uniform bearing of all its various parts, and the more gradual distribution of the moving load, possesses so great a practical superiority, that it will eventually altogether supersede the older and fundamental form. One of the chief points in the construction of a lattice girder is the determining the number of series of triangles which should be introduced into the web. It is in this particular, in fact, in which lies the true economy of the lattice form. If we have less than the correct number of crossings, the girder is laterally weak, and in order to give it the requisite degree

of rigidity we are compelled to employ bracing and stiffening irons. On the other hand, should the number of triangles be in excess, there is a corresponding loss of material in the superfluous ties and struts introduced, and a considerable quantity of unnecessary labor and workmanship incurred. This latter fault is especially visible in some of the earlier erections of this form of girder, and even at present, engineers are too much addicted to a superfluous multiplication of the crossings of the lattice bars. There is certainly some latitude respecting the number of series of triangles which may be economically inserted in the web; but it will be seen there is a minimum which cannot be departed from with safety. This minimum is determined by the amount of bearing which can be given to the tension or compression bar which undergoes the greatest amount of strain at its junction with the flanches, or, in other words, by the number of rivets which can be inserted in the last bar of the web, whether tie or strut, which bears directly over the edge of the abutment. The number of rivets which can be put in depends principally upon the size of the vertical side of the angle irons connecting the web and flanches together, and also to some extent upon the breadth of the bar itself (see Fig. 1.)

Fig. 1.



The bar could, of course, be made of sufficient scantling to bear the whole strain of $s = \frac{W}{2} \times \text{cosec } \theta$, the equation for the strain on the last bar of a triangular girder. This however could not be effected, in a girder exceeding moderate dimensions, without the employment of pins instead of rivets, as the connecting medium between the webs and booms. Such a substitution, as before stated, is not admissible in a lattice girder proper. In large and deep girders moreover, where, in order to preserve due economy in the distribution of the material, the crossings in the web are comparatively fewer than in smaller examples, and consequently there is a proportionally less amount of lateral stiffness, it is particularly necessary to preserve the correct ratio between the length and breadth of the bars. It is the latter dimension alone

which affects the distribution of the rivets, as a certain amount of margin must be left between the rivet hole and the edge of the bar. It may be remarked here, as one of the advantages of drilling over punching, that a hole may be drilled much nearer to the edge of a bar or plate, than punched, with the same impunity to the material. Practice, in this as well as in everything else, modifies the results of absolute theory.

In fig. 1, let a rivet be inserted in the bar F, as shown at E, and suppose a strain acting upon the bar and tending to cause a fracture in the direction of C D. Let x equal the margin required to be left outside the edge of the rivet-hole; d the diameter of the rivet; b the breadth, and t the thickness of the bar. In order that the bar and rivet might take the same strain theoretically, we should find the equation $dt = 2xt$, and $x = \frac{d}{2}$.

If punching be the method employed for obtaining the rivet-holes, x should never $< d$, and in general should equal $\frac{3d}{2}$. Should drilling be used, the value of x might be safely taken equal to d, and even sometimes less. There is no doubt that, were two bars joined by rivets, and their relative sections accurately and proportionately equalized for a constant strain, the superior toughness of the rivets would, when the point of fracture was arrived at, give them the advantage over the bars, and the latter would yield first. As x is always equal $\frac{b-d}{2}$ it is clear that the thickness of the bar has nothing to do with the space actually available for the insertion of the rivets, although it has a considerable influence upon the net section of the bar. It will be easily preceived that it is not the tension, but the compression bars, which virtually put a limit to the number of rivets, and consequently to the strain which can be borne at their junction with the flanches. We may increase the width of the bars in tension, comparatively to a great extent, but we cannot pursue the same course with those in compression. This will be evident if we refer to any of the sections of iron which are given as suitable for bars in compression, in fig. 2, *C. E. & A. Journal*, for March, 1863.* If we increase the lateral dimensions of any one portion of either the tee, channel, or angle irons employed as struts, we at once alter the shape of the section, and altogether lose the peculiar advantages resulting from the employment of that particular form of iron.

It will be found that, except in girders of very large spans, the struts will not take more than one rivet in their breadth. Let s be the strain resulting upon the end compression bar of the web, and which would require a certain number of rivets n to resist its action with safety. Suppose that the size of the vertical side of the angle irons which have been determined on in obtaining the area of the flanches and the probable breadth of the struts, will only leave room

* Journal Franklin Institute, page 232.

sufficient for the insertion of a number of rivets n_1. There will then be a consequent reduction in the amount of strain which can be borne by the strut, and which make equal to s_1. The following proportion will always hold, $\frac{n}{n_1} = \frac{s}{s_1}$. Let d equal the diameter of the rivets, which, unless for good reasons, should be of the same size as those employed in the flanches and other portions of the iron-work. From the neglect of this rule, I have known an instance where a workman has been busily engaged in riming out a hole, in order to make it sufficiently large for the insertion of a rivet which was intended for a totally different part of the girder.

From the above equation we find that the area of the rivets will be in direct proportion to the strain. If we put c for the constant, and make the area of the rivets equal to $\frac{\pi d^2}{4}$, we have the following equation for the strain:

$$s_1 = n_1 \times c \times \frac{\pi d^2}{4}.$$

The value of c is generally assumed as the same as that assigned to the plates and flanches, but it may with perfect security be taken considerably higher. From experiments which have been made with respect to the testing of the different forms of iron, it appears that, considering the rivet iron only equal in strength to that of the bars, we should find, putting c_1 for the strength of the plates, that

$$c = c_1 + \frac{c_1}{4}.$$

If Swedish iron were used, we should obtain a still higher value for c. Let N equal, as in the former notation, the number of series of triangles introduced into the web, and we find $N = \frac{s}{s_1}$. Substituting for s_1 its value $s_1 = n_1 \times c \times \frac{\pi d^2}{4}$ we obtain $N = \frac{4 \times s}{n_1 \times c \times \pi d^2}$. s is the strain which would come upon the last bar of the web, in the supposition that there were only one series of triangles, and was shown, in that portion of the subject which treated of the strains on the web, to have a maximum value of $s = \frac{w}{2} \times \operatorname{cosec} \theta$, and which occurred when the girder was subject to its full uniform load. Inserting this value in the above equation, we obtain

$$N = \frac{2 \times w \times \operatorname{cosec} \theta}{n_1 \times c \times \pi d^2}.$$

Making a equal the area of a rivet, and writing in for πd^2 its value $= 4 \times a$, we equate $N = \frac{w \times \operatorname{cosec} \theta}{2 \times a \times n_1 \times c}$.

In girders of small dimensions, where D the total depth may be assumed as the depth for calculating the strength of the girder, we shall always have practically λ the length of any lattice bar $= D \times \text{cosec } \theta$, and we may substitute this value in the equation, and obtain

$$N = \frac{W \times \lambda}{n_1 \times C \times a \times D}.$$

In girders of large span, where the depth available for calculation is not D, the depth from out to out, but a depth to be determined as D_1, the proportion between λ_1 and D_1 will still hold; the effective length of a lattice bar will not be λ, but λ_1, which would be measured from the same vertical points as D_1. We shall thus always have the equation $\lambda_1 = D_1 \times \text{cosec } \theta$.

Where the flanches are correctly proportioned, that is, where a due ratio is maintained between the area of the vertical and horizontal portions, it will be found, except in very large spans, that λ will closely approximate to λ_1. Whatever vertical position in the flanches D_1 may occupy, care should be taken that the attachment of the bars to the flanches should occur at or near those points. The injurious effect of any leverage would thus be obviated, which would otherwise arise were there any considerable distance between the points where the moments of the different forces of the web and flanches were brought into action.

The value of N determines the relative position of the crossings of the ties and struts, both with respect to each other and the flanches. An ordinary arrangement of the struts and ties is shown in fig. 1, where AB, CD, represent the centre lines respectively of a strut and tie, which cross each other at or near the centre of the vertical side of the angle irons connecting the web and flanches. The bars are riveted to the angle irons in the usual manner, and have one rivet passing through both bars at the centre of the crossing, as shown in the figure. This method slightly modified, is that usually employed in Warren and triangular girders, the difference being that no rivets are employed; the centre rivet alone, in the drawing, being replaced by a pin, which thus constitutes the sole connexion between each pair of bars and flanches. Where pins (which are with respect to rivets, of comparatively large diameter) are used, this may be perhaps the best and most economical method which could be employed, although open to objections. In a lattice girder, however, where the means of distributing the bearing over a number of points connecting the webs and flanches can be readily obtained, it is far otherwise. If we refer to the arrangement in fig. 1, where five rivets are shown at the intersections of the bars AB, CD, with the flanches, we at once perceive that in consequence of the rivets being so close together, there is a large amount of metal to be punched out of the angle iron within a very small space. Hence a local weakness must result in that portion of the flanch where the junction occurs. The strain also is too much restricted to one particular part of the flanch, instead of having as uniform a distribution as possible. A better position for the crossing

of the ties and struts, which takes place nearest the flanch, is shown at E (fig. 1). This position is also favorable for stiffening the girder, by joining the crossings with the opposite ones of the same web. In designing a lattice girder it is often advantageous to determine the distance between the intersections of the bars of the web, without going into the details of the drawing of an elevation of the girder. Having fixed approximately upon the position of E (see fig. 2), which should be relatively the same for both the top and bottom flanches, let λ equal the length of any bar between these points, and let N represent, as before, the number of triangles introduced into the web. The divided portions of the bars will be exactly proportional to the number of series of triangles, and each divided portion will thus equal $\frac{\lambda}{N}$. In the diagram let d be the distance required, and θ the angle of lattice = 45°, then $d = \frac{2 \times \lambda \times \text{cosec } \theta}{N}$. If we make D the vertical depth between the same points E, E to which λ is referred, we have $D = \lambda \times \text{cosec } \theta$, and, substituting this value in the above equation, we find $D = \frac{2 \times D}{N}$.

The same result may be arrived at as follows:—Let x equal the distance of the points E from the top and bottom flanches respectively, and call D_1 the total depth of the girder; then

$$D = (D_1 - 2x) \text{ and } d = \frac{2(D_1 - 2x)}{N}.$$

If $x = 0$, the arrangement becomes identical with the first part of fig. 1. If $x = 0$ and $N = 1$, we have $d = 2 \times D$, which is the value it would have in a pure triangular girder constructed with an angle of 45° instead of 60°, which is the angle usually employed in girders of that description. In a Warren girder $d = \lambda$, and as there are no crossings, d in this instance will equal the distance between the junction of any two ties and struts with the flanches. In small girders, and in cases where great accuracy is not required, as x is always relatively very small, we may consider $D = D_1$, and consequently

$$D = \frac{2 \times D_1}{N}.$$

In the particular class of girders we have chosen

$$D_1 = \frac{L}{12}, \text{ and } d = \frac{L}{6 \times N}.$$

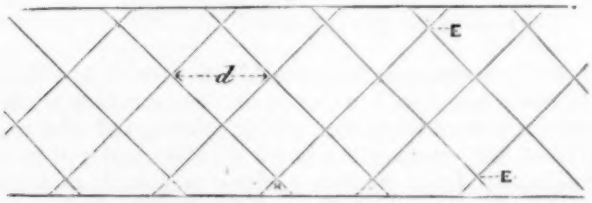
In calculating by this equation, if the value of d be taken to the nearest three inches, it will be found to give a result sufficiently accurate for practical purposes. It must be kept in mind that this neglect of the value of x is only theoretical. Its value, which is the position of E, E, must be left to the judgment of the designer: and is finally better determined by artifice than in any other manner, as no absolute rule can be given respecting it. It may be remarked that in any

lattice girder the distance between any two intersections of the tension and compression bars in the web should never exceed the total depth of the girder, or in other words, d should never $>$ D and it would be well not to $>$ D_1.

In bridges of large span, the web may be made considerably more open than in smaller spans, but the distance between the crossings follows no fixed proportion. In order to avoid all possibility of the lattice bars meeting at their intersections with one another, where they join the flanches in the objectionable manner shown in fig. 1, the value of x must lie between the limits of $x = 0$ and $x = \frac{d}{2}$. It will be useful to bear this fact in mind when drawing the elevation of the girder, or what amounts to the same—viz: that the total length of the lattice bars must be divided unequally; they may be divided equally between the points E, E (see fig. 2), but not throughout their whole length, or some of the intersections of the bars will be found to come too close to the flanches.

It is a very common arrangement in lattice girders to put one crossing in the centre of the web, no matter how many others there may be. In very small specimens where there are only two series of triangles, this must of necessity be the case, but otherwise there is no advantage to be gained by it; on the contrary, it is preferable to have two crossings each at an equal distance from the centre. There is an

Fig. 2.

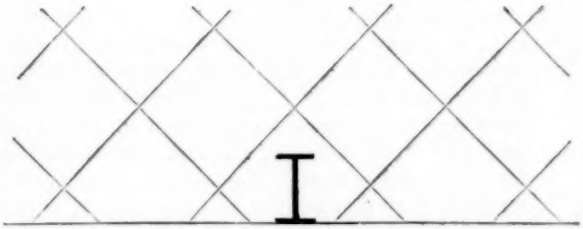


exceptional case, which ought never to occur, in which the load is placed at or near the centre of the depth of the girder, which is the worst position it could occupy; in such an instance it would be highly advisable to put a crossing in the centre of the web, as it would not only tend to stiffen the web at that point, but would also offer means of attaching to it various portions of the superstructure, without the necessity of making holes for bolts in those parts of the bars which had not been punched. In determining upon the intersections of the tension and compression bars which occur nearest to the flanches, or in other words, in fixing the position of the points E, E (see fig. 2), regard must be had to the manner in which the moving load, or live weight, as it is often called, is to be placed on the main girders. If it is to be simply superimposed upon them, either by the means of cross girders, or planking sufficiently strong laid upon the top booms, it will have no effect upon the crossings of the lattice bars, which may therefore be arranged independently of it, subject only to the conditions above mentioned. A similar arrangement respecting the lattice

bars may be carried out whenever the cross-beams supporting the superstructure and rails are suspended, either by bolts, straps, or any other medium, from the bottom booms. It may be mentioned here that this method of hanging the load from the girder, instead of placing it upon it, is not to be recommended, although it is sanctioned by some of the highest authorities in the profession. We shall return to this portion of the subject when treating on the effects of the different portions of the moving load on a girder.

When the load is placed upon the bottom booms of a lattice girder, and supported by cross-beams, either of wood or iron, which pass through the squares or diamonds formed by the intersections of the lattice bars, it will be seen on referring to fig. 3, which is self-explanatory, that the crossings must be so arranged that sufficient space is

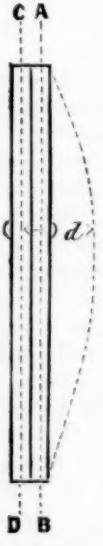
Fig. 3.



provided for the purpose. In the diagram the thick black lines represent a section of a cross girder, fitting in between the lattice bars, and resting upon the bottom flanch of the main girder. This is a mere matter of detail, and when the bridge is on the square there is no practical difficulty to be encountered in fixing the cross-beams in their proper places after the main girders have been erected. When however the bridge is on the skew, and the cross-beams are, as is very frequently the case, put in on the skew-line also—that is, parallel with the face of the abutment—it would be better to allow a somewhat wider space than what would just barely suffice to permit the passing of the cross-beams through the openings in the diamonds. One reason is, that it is very difficult to get the main girders fixed *in situ*, so that the two openings intended to receive the two ends of the same cross beam shall be exactly in the skew-line of the bridge, or, otherwise speaking exactly opposite to one another on the skew. The same difficulty, generally considerably augmented, occurs when the bridge is on the skew, but the cross-beams are put in on the square. This is nearly universally done, when the angle of skew is very sharp, as it shortens the span of the cross-beams, and consequently the amount of material and the cost is proportionally diminished. As in the former instance, it is seldom that, when the main girders are erected with their proper bearings on each abutment, that the two requisite openings will be found exactly opposite to one another. The result is, that the main girders must either be shifted, one one way, and another the other way, so as to bring the two openings square to one another; or

the cross-beams must be inserted a little on the skew, which varies with the obliquity of the openings of the two girders to one another. From want of due attention to this detail, trifling as it may seem, I have known an instance where it has been necessary, after the main girders were erected, to cut a small piece out of each lattice bar forming the diamonds or openings intended to receive the cross-beams, in order to admit the passage of the latter. It would be superfluous here to comment upon the unworkmanlike nature of such an alternative. In lattice girders designed for bridges on the skew, and where the load is carried by cross-beams put in on the square, it is evident that the arrangement of the openings will not be equidistant from the two ends of the same girder, that is, the two ends of the girder as far as the lattices are concerned will not be similar. This fact should not be disregarded, for it is a very common thing for girders to be sent out of the workshop with the whole span equally spaced or divded into openings for the cross-beams, so that the two ends are similarly formed. In many instances the dimensions of the openings, or distance between the intersections of the bars, may not differ more than half an inch from those given in the drawings, and it is only after the main girders are erected and the cross-beams are found not to fit that the difference is discovered. The two main girders may be constructed perfectly similar to one another, only care must be taken that they be turned end for end when erected. In other words, the two dissimilarly formed ends must rest on the same abutment, and the intended openings will then come exactly opposite to each other on the square. In the portion of our subject which treated of the strains upon the web, it was mentioned that although theoretically there might be some slight strain brought upon the rivets connecting the intersections of the tension and compression bars, yet practically they might be disregarded. If we consider the relative states of equilibrium the tension and compression bars are in, under a normal strain, the former in stable and the latter in unstable equilibrium, we shall find that the only force which would tend to produce a direct strain at the crossings of the ties and struts would be that generated by the deflection of the struts. We exclude for the present any consideration of the effects of any strain which might be induced by the absolute deflection of the whole girder under a moving load.

Fig. 4.



With a large deflection, but greater than what would occur even under a test load, the effect of the strain would be to cause an appreciable shortening or lengthening of the lattice bars; this contraction or extension of the bars would vary according as the booms were equally or unequally rigid. In fig. 4, let A B, C D, represent the centre lines of a strut and tie respectively, as they would appear in the section of the web of a lattice girder. Suppose the strut A B to be deflected, by any force whatever, out of the plane of the web into the position shown

by the dotted curved line. This deflection will produce a longitudinal strain upon the tie C D, which can only be brought upon it through the rivet inserted at their common intersection. If we make S equal the normal strain upon the strut A B, and S_1 that induced upon the tie C D, and calling d the amount of deflection that the strut undergoes at the point of junction, which for simplicity's sake we will suppose to be at the centre of the web, or nearly so, we have the following proportion, $S_1 : S :: d : \frac{\lambda}{2}$; λ being, as before, the length of the strut between the points where the forces tending to cause deflection commence to act; from which we obtain

$$S_1 = \frac{S \times d \times 2}{\lambda}.$$

The general value for S under a uniform load is

$$S = \frac{W\,(L - 2a) \times \operatorname{cosec} \theta}{4 \times L \times n}.$$

Substituting thus in the equation found above, we have

$$S_1 = \frac{W\,(L - 2a) \times d}{2 \times L \times N \times \lambda} \times \operatorname{cosec} \theta.$$

Making use of our usual proportion, $L = 12 \times D$, and bearing in mind that the length of any lattice bar $\lambda = D \times \operatorname{cosec} \theta$, we finally obtain

$$S_1 = W \frac{(12 \times D - 2a)}{24 \times D^2} \times \frac{d}{N}.$$

The greatest deflection of the struts, and consequently the greatest longitudinal strain upon the ties in connexion with them, will take place when the maximum load is brought upon the girder. For the maximum strain upon the struts at the abutment, or those immediately over the commencement of the bearings, the equation is

$$S = \frac{W}{4 \times N} \times \operatorname{cosec} \theta.$$

Our value for W is

$$W = \frac{3 \times L}{2} = 18 \times D,$$

and making similar substitutions as above, we find $S_1 = \frac{9 \times d}{N}$. At the centre of the girder $S = \frac{w_1}{16 \times N} \times \operatorname{cosec} \theta$, and reducing as before, we attain $S_1 = \frac{3 \times d}{2 \times N}$. Calling S_2 this latter strain on the central diagonals of the web, we find that $S_1 : S_2 :: 9 : \frac{3}{2}$, or the strain upon a tie at the abutment resulting from the contiguous action of a strut is equal to six times the strain upon a tie at the centre. As the strains brought by the rivets upon the ties are exactly proportional to those

acting upon the struts in connexion with them, this conclusion might have been inferred *à priori* as follows :—

The maximum strain on the last diagonal at the abutment

$$= s_1 = \left(\frac{w}{2} + \frac{w_1}{2}\right) \times \text{cosec } \theta.$$

Putting w and w_1 in terms of the span,

$$s_1 = \frac{3 \times \text{L}}{8 \times \text{N}} \times \text{cosec } \theta.$$

Similarly, at the centre

$$s_2 = \frac{\text{L} \times \text{cosec } \theta}{16 \times \text{N}} \text{ and } s_1 = 6 \times s_2.$$

It is manifest that the proportion of d to $\frac{\lambda}{2}$ will always be very small, even when the struts are composed of a plain bar section. This fact, combined with a frequent repetition of the crossings of the ties and struts, is the reason of the otherwise singular stiffness and rigidity of the webs of the early examples of lattice girders, which were so constructed, and may serve as some excuse for their introduction. When a proper section of iron is chosen for the struts the ratio of d to $\frac{\lambda}{2}$ may be practically considered as equal to zero, except perhaps under a very severe test load. Having in the above investigation taken the crossing as occurring at the centre of the web, the above strains will be the greatest that could occur throughout any part of the tie. For the strain at any other part of the tie where the crossing of a strut might take place, we have merely to substitute for $\frac{\lambda}{2}$ its value, such as l, which would be the distance from the crossing to the point where the strain was brought upon the strut, and the ratio will always hold of d to l.

In concluding this portion of the subject, it may be remarked that to the theoretical and scientific knowledge necessary for the designing of iron bridges, must be added the skill of an efficient draughtsman. It is not to be supposed that when the strains are calculated, and the principal parts of the girder duly proportioned to them, that the thing is done. Far from it, the major portion of the work has yet to be completed, in the working out the details and putting them on paper. There is a great difference between the mere design or idea of a bridge, and the practical carrying out of that design; and thus it is that many a person will design a magnificent structure in theory, but which would prove perfectly unfeasible in practice. While the working drawings also are in progress, a number of minor advantages and improvements will be constantly perceived, which would never present themselves to the eye of the designer employed solely on theoretic calculations. As a rule, it will be found the most advantageous for the theory and practice, the cal-

culations and the drawings, to aid one another and to proceed *pari passu*.

We propose in the next to consider the jointing of the different parts of a lattice girder, which as far as the web is concerned offers some points of difference compared with girders of other descriptions.

(To be Continued.)

Experiments made at Watford on the Vibrations occasioned by Railway Trains passing through a Tunnel. By Sir JAMES SOUTH, LL.D., F. R. S., Member of the Board of Visitors of the Royal Observatory, Greenwich.

From the London Artizan, Sept., 1863.

These experiments were made in consequence of an attempt in 1846, to run a line of railway through Greenwich Park, in what seemed to several competent judges a dangerous proximity to the Royal Observatory.

It was abandoned, but (as Sir James South was informed) only for a time; and he thought it right to make some examination of the probable effects of such a vicinity, especially as to the power of a tunnel in deadening the vibrations.

The Watford tunnel was chosen as the observing station, being, on the high authority of Mr. Warburton, in ground very analogous to that on which the Royal Observatory stands; and every facility for making observations was afforded by the late Earl of Essex, through whose park and preserves this tunnel passes.

As the chief inconvenience to be feared from the proposed railway was the disturbance of the observations by reflection in mercury, it seemed best to take a series of these under circumstances as nearly as possible resembling those which might be expected at Greenwich. An Observatory was therefore erected, in which a large and powerful transit-instrument was mounted, with all the attention to stability that could be given in a first-class Observatory; and it had sufficient azimutnal motion to enable the observer to follow the Pole-star in its whole course; so that night or day (if clear), he could have the reflected image of the star in the mercurial vessel, ready to testify against the tremors caused by any train.

The distance of the vessel from the nearest part of the tunnel was 302 yards, that proposed for Greenwich being 286 yards. The length of the tunnel is 1812 yards; its southern or London end is 643 yards from where the mercury was placed, its northern or Tring end 1281 yards; and about 54 feet of chalk and gravel lie above the brickwork of its crown. The author's preparations were not complete till December 1846, and then a continuance of cloudy weather interfered with observation till January the 11th, 1847, when, and on the following nights, he obtained results so decisive, that he felt it his duty to communicate them at once to the then first Lord of the Admiralty, the late Lord Auckland, who was so satisfied with them that in a let-

ter to Sir James, dated "Admiralty, Jan. 26, 1847," he recorded the impression they had made on his mind in the following terms:—"They would be quite conclusive if the question of carrying a tunnel through Greenwich Park were again to be agitated." Sir James, however, continued the work to the end of March.

With the ordinary disturbance to which an Observatory is liable, (as wind, carriages, or persons moving near it,) the reflected image of a star breaks up into a line of stars, perpendicular to the longest side of the mercury vessel. With increased agitation, another line of stars perpendicular to the first appears, making a cross. With still more the cross becomes a series of parallel lines of stars; still more makes the image oscillate; and at last all becomes a confused mass of nebulous light. The first of these (the line) is not injurious to one class of observations; but the others are, and therefore the second (the cross) was taken as a measure of the beginning and end of injurious disturbance. Signal shots were fired when a train passed the southern entrance of the tunnel, and a shaft 1162 yards from it. Hence the train's velocity was obtained, and thence its position at any given time.

Upwards of 230 observations are given in detail, and their most important results are shown in a table, which contains the date, the distances at which the cross of stars begins and ceases to be visible, those at which the series of parallel lines is seen, the velocity in miles per hour, the weight of each engine, and also the length and weight of each train (when it could be identified).

This table proves that *in all cases* but one (which in fact is scarcely an exception) there is sufficient vibration to excite the cross at 670 yards, and that in 24 per cent. of the number it is seen beyond 1000, its maximum being 1176. At the southern end such disturbances reach far beyond the tunnel, while at the north they fall within it. From comparing them in the two cases, the author infers that the train's agitation extends laterally as far when it is in the tunnel as when in the open cutting. The amount of disturbance does not depend solely on the velocity and weight of the train, but also on other circumstances, of which prolonged action and length of train are the chief. In one instance, with only a velocity of 11·4 miles, the cross was seen at 1110 yards—a proof that no regulation of the speed in passing an Observatory at a distance of 300 or 400 yards would be of any avail.

The system of parallel lines is only seen between lines making angles of 45° with the perpendicular to the rails, that is, at distances under 427 yards; it scarcely ever is produced unless the cross be visible beyond 1000 yards.

These forms are also produced by the reports of cannon of twelve ounces calibre, at distances from 300 to 3000 yards; in the last case there is but a faint trace of the cross. In all, the appearance is momentary, not lasting in any case more than a second and a half. They are not produced by the roar of a two pound rocket fired 82 feet from the mercury, though very loud. When the cannon were fired *in the*

tunnel, where the perpendicular meets it, *two* sets of tremors were seen—one, he believes, propagated through the ground, the other through the air about a second later, the sound escaping probably through the shafts. Attempts were made to substantiate or refute this hypothesis; but the difficulties of *rapidly* shifting and unshifting the coverings prepared for the purpose were such as to compel him to relinquish it.

These observations were reduced in 1847; but conceiving all danger to the Royal Observatory was past, the author did not think it necessary then to proceed with them. As, however, no Observatory can now be considered secure from railway injury, he wishes to make them public, in hopes that they may be useful, not only to practical astronomy, but to some other departments of science.

A New Railway Signal.

From the London Mechanics' Magazine, July, 1863.

Travelers on the Midland Railway, passing Kegworth, may have observed at that place a new signal which is likely to cause a revolution in railway signals. It consists of a clock, with a face four feet in diameter, placed on the top of a column fifteen feet high. Only a quarter of the clock is shown, which is formed of ground glass, with red figures 0.5.10.15., and has only one hand. Attached to the clock is a long rod connected with a treadle about sixteen feet long, which lies along the inside of one of the rails. On the train passing over the treadle it is depressed slightly by the wheel flanch, and the clock hand is set at liberty and is so adjusted by a counterpoise that it turns to the figure 0. Immediately the train has passed over the hand begins again to mark the time up to 15 minutes, when it is stopped, thus indicating to the next train exactly how long up to 15 minutes the preceding train has passed the signal. The same clock works two faces, one for the up and one for the down line. The signal is illuminated at night. The simplicity of this signal is such, that it is almost an impossibility for it to get out of order, and it is so arranged that a passing train takes off all pressure from the clock, so that the great difficulty hitherto experienced in self-working signals is successfully overcome. The Midland Railway Company, who have erected the one above described, have every reason to be satisfied with the result of the experiment. It is calculated that when adopted double the number of night trains may be safely passed over the line that can be passed over now. There can be little doubt that it will prevent a great number of accidents from trains running into each other; and placed at mouths of tunnels will be of great service. The inventor of this ingenious contrivance is Mr. John King, lace manufacturer, Heanor.

MECHANICS, PHYSICS, AND CHEMISTRY.

On the Relations between the Safe Load and the Ultimate Strength of Iron.

By ZERAH COLBURN.

From the London Artizan, April, 1863.

(Continued from page 201.)

In employing iron in any structure where it is subjected to strain, we seek to keep within its limit of elasticity. Yet not only have we but a comparatively small number of recorded experiments to show us what this limit is, even under a single and temporary strain, but we have at least the result of M. Vicat's experiments to show us that we cannot depend upon any thing like this limit under a long-continued strain. What experimental knowledge we have goes to show that the original elastic limit of iron is greater when hammered than when rolled, but we are unable to count with any degree of certainty upon the ultimate superiority of hammered iron, in this respect, after long continued strain. As a rule, also—the abundent evidence of which it is not, perhaps, necessary to introduce into the present paper—all harsh, hard, crystalline irons have a higher elastic limit, in proportion to their breaking strength, than soft, ductile, highly fibrous irons, like Swedish bar, for example; that is to say, the harder irons will bear a greater strain before taking a permanent set, although, as we shall presently have occasion to inquire, it may not follow that they are really superior to other irons which are more readily stretched, and which, indeed, may have an even less breaking weight. What information we have goes to show that there is no settled relation between the elastic limit and the breaking weight of iron; the former is much more variable than the latter, and can hardly be expressed at all as an average result, ranging, as it does, from less than one-fourth to more than two-thirds of the breaking weight; or if the elastic limit be taken irrespective of the breaking weight, the instances already cited show that the former varies from $3\frac{1}{4}$ tons up to $24\frac{1}{2}$ tons per sq. inch in different qualities of iron, although the range in ordinary bar iron and plate iron is not nearly as great. Now, no engineer, in apportioning the strains in a structure, would think of working up to or near to the breaking strength of iron. His object is to keep within the elastic power of the iron as exerted through a very long series of years. We ought by this time to have hundreds of trustworthy experiments upon this point where there is now one. If the safe working strength of a metal is limited, as it would appear to be, by its measure of permanent perfect elasticity, we may say that we hardly know, even yet, what is the strength of the materials we are constantly dealing with, notwithstanding that not a year passes without some addition to our stock of knowledge of breaking weights.

While we are about considering the permanent injury which iron suffers when strained beyond its elastic limit, it is to be understood that iron may be strained for a short time almost up to the breaking point without in the least diminishing its strength under a breaking

weight subsequently applied. Indeed, in gradually applying the breaking strain to any sample of iron, it is clear that it must have borne 10 tons before it is subjected to a strain of 15 tons, and that it must have borne 15 tons before it is strained to 20 tons, and so on. Not only is this the case, but after a bar of iron has been actually broken under a tensile strain, the two broken portions of the bar will almost always require a still higher strain to break them. The weakest spot in the bar will fail first; and although the breaking strain will at the same time permanently stretch the bar throughout its whole length, the iron on each side of the fracture will still have its original breaking strength. Professor Barlow's Treatise on the Strength of Materials, contains the results of several experiments made at Woolwich Dockyard, as follows:

A bolt of Solly's patent iron was nicked at one place, and then broken by a strain of 26·7 tons per square inch. One of the pieces was then tried and broke at 29¼ tons. In the next experiment a bar of the same iron was first broken with 23½ tons per square inch, then again with 26½ tons, a third time with 26½ tons, and a fourth time with 25¾ tons.

Mr. Thomas Lloyd, engineer to the Admiralty, made a like series of experiments a few years ago, on ten bars of SC crown iron 1⅜ ins. in diameter, and 4½ feet long. The mean breaking weight at the first breakage was 23·94 tons per square inch. At the second breakage, with pieces 3 feet long, the mean strength was 25·86 tons per square inch. At the third breakage, with pieces 2 feet long, 27·06 tons per square inch, and at the fourth breakage, with 15 inches lengths, 29·2 tons per square inch. Mr. Lloyd's experiments have been held to show that iron was actually strengthened by stretching it; or, in other words, that by destroying the cohesion at one point, the cohesion was everywhere else increased. A more obvious explanation is, that the bars first broke at the weakest part, then, again, at the next weakest part, and so on. A variation of from 23·94 tons to 29·2 tons in the strength of the same bar is undoubtedly large, the greater strength being 22 per cent. more than the lesser; a difference which appeared to exist in each of the ten bars tried. It is well known, however, that hardly any two bars of iron have exactly the same strength, and Mr. William Roberts, manager of Messrs. Brown, Lenox & Co.'s extensive chain cable works at Millwall, has cut a 12 foot bar of iron into 2 foot lengths, and found on testing that there was a difference of strength of 20 per cent. between the strongest and the weakest of these pieces. In the experiments of the Railway Iron Commission upon the extension of cast iron, the strength of Lowmoor cast bars was 7·325 tons per square inch at the first, and 8·152 tons at the second breakage. Blaenavon iron broke with 6·551 tons per square inch at the first, and 6·738 tons at the second breakage. Gartsherrie iron broke with 7·567 tons per square inch at the first, and 8·475 tons at the second breakage. Other cast iron bars of a certain mixture broke with 6·6125 tons per square inch at the first, and 6·777 tons

at the second breakage, the latter being at an unsound place. Upon these results the commissioners remarked that "it would appear that iron, repeatedly broken, becomes more tenacious than it was originally. This erroneous conclusion may be obviated by considering that it would be very difficult, if not impracticable, to obtain cast iron bars perfectly sound and 50 feet long. Fracture may be supposed to take place the first time at the largest defect, and subsequently at those smaller, until, finally, none remain." It is not intended, however, in the present paper, to entirely deny that the breaking strength of iron may be actually increased by being stretched when cold; and this point may be left as an open question. That iron is so strengthened derives some probability from the known fact that its strength is greatly increased by being drawn cold into wire, and also by cold rolling. When heated moderately, or to less than a dull red, and then stretched, iron is strengthened throughout. This treament is known as thermo-tension, and in an extensive course of experiments made about twenty years ago by Professor Walter R. Johnson, for the United States Government, a total gain of nearly 30 per cent. in strength and length, taken together, was estimated to have been obtained with a variety of irons. A bar of iron, having a strength of 60 tons, was heated to upwards of 500 degrees, and then stretched by 6½ per cent. of its length, when it acquired a strength of 72 tons. Captain Blakely has lately proposed the same treatment of iron, and his experiments, it is understood, corroborate those of Professor Johnson. All the links made for the four great pitch chains employed, with the steamship *Great Britain's* engines, for getting up the speed of the screw, were stretched ½ inch while at a dull red heat.

But from what has been said, it is not to be supposed that iron is not injured by excessive strains, notwithstanding that the metal strained may, when tried immediately afterwards, still retain its full breaking strength. The injury will appear when a subsequent working strain is long continued; and even without waiting for this, it will be found that the strained iron has been deprived of a large part, if not the whole, of its natural elasticity. In a paper of great value, read nearly seven years ago before the Royal Irish Academy, and afterwards published in a quarto volume entitled "On the Physical Conditions involved in the Construction of Artillery," Mr. Robert Mallet has laid down a useful measure of the working and ultimate strength of iron. Poncelet had already employed co-efficients which indirectly expressed, not merely the elastic limit and breaking strength of iron, but the range also through which the force acted in each case in reaching these limits. Mr. Mallet has adapted these co-efficients to the English standard of mechanical work, to wit, "foot-pounds," and he represents the structural value of different materials, or of various qualities of the same material, in one case by the product of the elastic load in pounds into half the range in feet or parts of a foot through which it acts, and in the other case by the breaking weight in pounds multiplied also by half the range, in feet or parts of a foot, through which it acts. Mr. Mallet employs Poncelet's co-efficients, as follows:

Te = foot pounds in reaching elastic limit of tension.
Tr = " " to produce rupture by tension.
T^1e = " " in reaching elastic limit in compression.
T^1r = " " to produce crushing.

One-half the weight into the whole extension, or, what is the same thing, the whole weight into half the extension, is adopted, because the force gradually applied to break a bar must increase from nothing to the breaking weight. Upon Dr. Hooke's law *ut tensio sic vis*, the weight of a grain will in some minute degree deflect or extend the heaviest bar of iron, and the deflection or extension will increase progressively, with the weight applied, up to rupture. Therefore, if a bar be stretched 1 foot and then broken with a weight of 33,000 pounds, the work done will be the mean of zero and 33,000 pounds into 1 foot or 16,500 foot-pounds. This, as has been said, is the work done in the case of a gradually applied strain. If, however, the weight be applied without impact, but at the same time instantaneously, upon the bar, it will, so long as the limit of elasticity is not exceeded, and supposing the bar to have no inertia, produce twice its former deflection, and therefore, twice the ultimate strain. For the weight, in falling through the distance of the deflection due to the load at rest, will acquire momentum sufficient to carry it through an additional distance equal to that of the static deflection. This may be best demonstrated experimentally with the aid of a spring balance. If, upon the pan of a balance sufficiently strong to weigh up to 40 pounds, a weight of 15 pounds be placed, and this be then lifted to zero on the scale and there released, it will descend, momentarily, to nearly 30 pounds on the scale; and if there were no opposing resistances and the spring had no inertia, it would descend to exactly 30 pounds. In the actual application of strains in practice, a weight is never thus applied, but a consideration of what would occur under such circumstances, is sufficient to show how important it is that vibratory action be not overlooked in considering the strains on bridges. It is to be remembered that this action of suddenly applied loads is only manifested in the case of the application of weights, for if the strain be produced by the sudden admission of steam or any other practically imponderable body, no additional deflection will take place beyond that due to the pressure acting statically. If steam pressure acted in the same manner in this respect as a weight, the steam indicator would show nearly or quite double the pressure acting effectively within the cylinder of the engine.

It will not be attempted in the present paper to enter fully into the application of the co-efficients adopted by Mr. Mallet, for there are objections against, as well as reasons in favor of, their application. It is evident that Tr may be the same in two cases, in one of which a high breaking weight is exerted through a very short distance, and in the other of which a low breaking weight produces stretching through a correspondingly greater distance. But this co-efficient does possess a value in taking account of the combined cohesive force and extensibility of iron, instead of the breaking strength alone. As Mr. Mallet

justly observes, glass has a high cohesive force, and is nevertheless useless under strain, owing to its brittleness, while caoutchouc has great extensibility or toughness with but slight cohesion. The products, therefore, expressed by the co-efficients in question do not afford a complete notion of the practical value of a given material unless the factors whereby these products are obtained are also given. The elastic limit of iron, however low, is not to be exceeded in practical use, whatever its range of elasticity may be; nor does it appear prudent to work into the neighborhood of a high elastic limit when the elastic range is known to be small. It is not to be understood that the co-efficients in question are intended to apply otherwise than in comparison of bars of equal length, else it would result that the measure of *Te* in a bar of 50 feet long was one hundred times greater than that of a bolt 6 inches long, and of the same material and sectional area. For the purposes of the engineer, a long bolt is not only no stronger than a short one, but as it can be no stronger than its weakest part, it will follow that the average strength of 100 bolts 6 inches long is likely to be greater than that of a single bolt of the same diameter and 50 feet long. Every engineer must be aware of the importance of toughness in combination with cohesive strength in iron, but we need much more extensive and accurate information as to the former; and a consideration of Mr. Mallet's co-efficient should lead to additional experiments being undertaken. Mr. Kirkaldy, proceeding upon an independent course of inquiry, but with the same object as that pursued by Mr. Mallet, has lately published the results of a most important series of experiments, which are the first upon any thing like an extensive scale, to take into account the combined cohesive force and extensibility of iron and steel. Mr. Kirkaldy experimented upon many hundreds of specimens, but he did not ascertain their limit of elasticity. He has given both the original dimensions and cross sectional area, and the dimensions and area after fracture, and he has also given the amount of elongation at fracture, although he did not ascertain the extension at the elastic limit. The reduction of diameter of a bar at the point of fracture serves to give a practical man a good idea of the quality of the iron, but it does not admit of an expression of the mechanical work done in producing fracture, as does the combined breaking weight and linear extension. In tearing a bar in two, also, we have to consider the permanent stretch communicated to all parts of the bar alike, and the additional stretch at and near the point of fracture. That part of the stretching which extends uniformly throughout the whole bar would, we may suppose, be exactly proportional to the length of the bar, while that part of the stretch which takes place close to the point of fracture would, we may also suppose, be a fixed quantity, whatever might be the length of the bar. Mr. Kirkaldy's specimens of iron and steel varied from 2·4 ins. to 8·2 ins. only in length, and with these the ultimate elongation at fracture varied from nearly nothing to 27 per cent. of the original length, whereas longer bars would have shown a proportionally less elongation. The samples which hardly elongated at all were of puddled steel ship

plates. One sample, which bore 63,098 pounds per square inch of the original area, stretched before breaking but the $\frac{1}{20}$th part of an inch in a length of 7·6 inches, or less than $\frac{7}{10}$ths of 1 per cent. of the length. Adapting to Mr. Mallet's co-efficient, the structural value of such a material would be almost nothing. In fact, Mr. Kirkaldy found the puddled steel plates throughout to have much less extensibility than cast steel plates, while the former also were of very irregular breaking strength.

Mr. Fairbairn communicated some of the results of an important series of experiments to the British Association at the Manchester meeting, 1861, from which it appeared that a large model of a wrought iron plate girder withstood without injury, 1,000,000 applications of a load equal to one-fourth its breaking weight, and afterwards 5175 applications of one-half its breaking weight, when it broke down. The model was then repaired, and 25,900 applications of two-fifths its breaking weight, and afterwards nearly 3,000,000 applications of one-third its breaking weight, were made, it was said, without injury, although neither the deflections nor the permanent set were given. We know that iron alters its form, temporarily, during the application of very moderate strains, the elasticity of good iron being generally observable with strains of 1 ton per square inch; and we know that its form is permanently changed both immediately on exceeding the limit of elasticity, and gradually under strains nearly approaching that limit. There clearly must be a re-arrangement of the particles of iron always going on where the strain is great; and as we know that when even a more moderate strain is eased off the iron tends to resume its original form, it appears incontestible that final injury must result under what may appear moderate although irregular loads—say, one-third, or even rather less, of the breaking weight. Iron, it is still to be remembered, has not been employed long enough for purposes of construction to enable us to compare its endurance with masonry, of which there are abundant examples still perfect after many hundred years. At the same time it must not be forgotten that while we can never know the absolute strength of a bar of iron without destroying it under strain, neither can we always infer its strength from its deflection, or apparent range of elasticity, for we are not yet secure against flaws or those other faults of molecular structure, which Mr. Mallet so well describes as "planes of weakness." A bar of iron may have a general strength of 22 tons per square inch, except at a single point in its length, where, for an almost inappreciable linear distance, the strength may not exceed 10 tons. If the bar be broken, this fault will be detected, but hardly, if at all, otherwise; for under a strain of even 8 tons or 9 tons, the extension at the precise point of weakness would be so slight as to be quite overlooked in a general observation of the total deflection or extension.

The application of iron to bridges, especially to those of large span, necessarily requires the most careful consideration in apportioning the strains, since every pound of metal not brought into effective action, is so much dead weight or useless load—being not only mis-applied

of itself, but requiring additional material to support it. In considering the strains upon iron, therefore, reference has been more particularly made in the present paper to its employment in bridges, but in the case of boilers, iron ships, cranes, ordnance, railway bars, warehouse girders and columns, roofs, engine beams, and in many other applications, the most careful distribution of material and adjustment of strains is of very great importance. Iron is, perhaps, more severely strained in steam boilers, than in any other structures. In the case of locomotive engines, there is a disposition to employ still larger boilers and to carry still greater pressures. With 50-inch boilers, formed of $\frac{7}{16}$-in. plates double riveted, and carrying, as is now not unusual, from 130 pounds to 150 pounds pressure, there is at the higher limit a circumferential strain of $5\frac{1}{2}$ tons per square inch at the joints and a longitudinal strain of nearly 2 tons per square inch along the whole length of the boiler: the resulting strain at the joints being nearly six tons per square inch. This strain is constantly maintained with plates ranging from 21 tons to 24 tons in strength, and under all the contingencies of corrosion, incessant vibration, and occasional sudden exaltations of pressure due to the instantaneous production of steam upon overheated tubes or plates. In many cases we have 4 feet boilers with $\frac{3}{8}$-inch plates single riveted and worked at 120 pounds, corresponding to a strain of at least $6\frac{1}{2}$ tons per square inch at the joints of the boiler when new: the circumferential and longitudinal strains being both taken here into account. Put under this strain when new, many locomotive boilers are worked in all for from ten to twenty years, and often from three to seven years without any internal examination of the plates. It is not remarkable, therefore, that explosions are becoming so frequent.

We may regard with much hope the increasing use of steel in large masses, as produced by Krupp and by Mr. Bessemer, and others, whose discoveries have already effected a great economy in the production of that material. Although a departure from the subject of the present paper, it is interesting also to refer to the introduction of phosphorized copper, as now produced by the Birmingham and other coppermasters. It was announced, about three years ago, as a new discovery by Mr. Abel, chemist to the War department, that the addition of from 2 to 4 per cent. of phosphorus to copper greatly increased its density and strength. There is no doubt of the large advantage of this combination, although it was discovered in the last century, and made publicly known sixty years ago. A French chemist, M. Sage, contributed a paper upon this subject to the *Journal de Physique*, and which was translated into the 20th volume of the *Philosophical Magazine*, for 1805. By combining the maximum quantity of phosphorus with copper, the latter acquired the hardness, grain, and color of steel, and although M. Sage had already kept the compound for fifteen years, it had suffered no change from exposure to the air. It was easily turned and took a fine polish. It may yet be found that copper thus treated is the best material for many of the purposes of the mechanical engineer.

The Scientific Balloon Ascent.

From the London Athenæum, July, 1863.

In my eleventh ascent,—that from Wolverton,—I had furnished myself with a second spectroscope, whose slit I could open at pleasure, leaving the larger with its slit adjusted for observations on the sun itself.

The circumstances of the ascent, however, were so remarkable, experiencing clouds to the height of 4 miles, and encountering a snow-storm on descending, from 3 miles to 2 miles, that I had no opportunity of using the larger spectroscope at all, and the smaller for a few minutes only, at our highest elevation, viz: exceeding 4 miles; there the sky was of a very pale blue color, the atmosphere was misty, and the spectrum as seen through the small spectroscope was exactly as when viewed from the earth when the air is misty and the sky of the same degree of faint blue.

The action of the wet-bulb thermometer on this occasion, when the temperature was approaching to and passing below 32°, was remarkable; its reading continued to descend to 26°, whilst the reading of the dry-bulb was above 32°; but on the latter passing below 32° the wet-bulb increased to 32°, and continued there for some time, whilst the dry-bulb continued to decrease; then a slight decrease of the wet to 31° took place, and then very suddenly it passed to its proper reading some degrees below the dry, and then acted well at all temperatures till the reading of the dry-bulb ascended above 32°; its proper action was then checked for a time, till, in fact, all the ice was melted from the conducting thread and bulb, a process which alone can be performed in the situation by taking the bulb and conducting thread into the mouth, being, in fact, the only source of heat at command. Mr. Lowe had forwarded to me to Wolverton, on the day of ascent, several bottles of ozone powders made from starch, derived from different grains and vegetables; but the circumstances were not favorable; they were all, however, deeply tinged, whilst ozone papers were very slightly colored.

At the highest point reached, about 4¼ miles, the sky was very much covered with cirrus clouds; the sky as seen between them was of a very faint blue; as seen from below through a moist atmosphere we were above clouds, but there were no fine views or forms; all was confused and dirty-looking,—no bright shining surfaces, or anything picturesque,—and the view was exceedingly limited, owing to the thick and murky atmosphere.

At 2 h. 3 m., on descending, we lost even the faint sun, and re-entered fog, and experienced a decline of temperature of 9° in little more than a minute. At 2 h. 6 m. there were faint gleams of light; fog was both above and below, but not near us. At 2 h. 7 m. large drops of water fell from the balloon, covering my note book: the next minute we were enveloped in fog, which became very thin at 2 h. 14 m. At 2 h. 14½ m. rain fell pattering on the balloon; this was shortly succeeded by snow, and for a space of nearly 4000 feet we passed

through a snow storm; there were many spiculæ, and cross-spiculæ, with snow crystals small in size, but distinct; there were few, if any, flakes; as we descended the snow seemed to rise above us.

At 2 h. 17 m. we passed below the regions of snow, and shortly afterwards we saw a canal and then another, each being straight for miles apparently. The state of the lower atmosphere was most remarkable: Mr. Coxwell had never seen it so murky before; when far from a town, it was of a brownish, yellowish tinge, and remarkably dull. No distance on land could be seen.

When at the height of 1 mile, we had no more sand, and simply became a falling body, checked somewhat by the balloon; we threw away leaden weights, &c., to help check the rapidity of descent. The ground wind was strong, and the descent was somewhat rough; we rebounded from the earth three or four times, and finally the grapnel caught in a water-course.

Photographic papers of two kinds were taken up, the one prepared with iodide of silver, and the other with chloride of silver, and arrangements were made that both kinds, parts of the same sheets of paper, should be observed at Greenwich in the first minute of every five minutes from noon to 5 o'clock. The comparison of results show all much deeper colors at Greenwich at first, but the sky at Greenwich was not cloudy for three hours after it was overcast at Wolverton, but coloration of both kinds of paper under a cloudy sky was very nearly the same as that in the balloon. JAMES GLAISHER.

Blackheath, July 6th, 1863.

Translated for the Journal of the Franklin Institute.

New Process for Photo-lithography.

M. Morvan is the inventor of the following process, by which all kinds of drawings and engravings, whether manuscript or printed, may be reproduced on stone simply and rapidly.

The stone is first covered by the pencil with a thin coat of a varnish composed of 50 grammes of bi-chromate of ammonia, 300 grammes of albumen, and 300 grammes of water. When the surface is dry, it is exposed to the light under the object which is to be reproduced. The time of exposure depends upon the opacity of the object and the intensity of the light; but as a mean, we may say, that it will require from two to three minutes in full sunshine, and ten minutes in the shade. When the object is removed from the surface of the stone, which must be done in a dark room, nothing is seen upon the surface; but if the stone be washed with white soap, the soluble parts (that is those which have been protected from the light) are washed away and the stone is slightly eaten away in the parts thus exposed; while, wherever the light has been felt, the oxide of chrome formed by its action resists the corrosion of the soap; thus the image appears. In inking, the surface of the stone is first covered by a thin sheet of water, and the inking roller charged with the fat-ink passed over it; the ink can only adhere in the hollows, it is repelled by the water on the

reliefs; the hollows therefore furnish the shadows and the reliefs the lights of the impression; and as these reliefs were the lights and the hollows corresponded to the shadows of the original picture, it will be seen that a *positive* and direct copy is formed, and the original is in nowise injured, since it was laid upon the dry surface of the stone. By allowing the soap to remain upon the stone the impression is made deeper and the depth can be made to suit our purposes, the ordinary time is about a quarter of an hour, after which we may proceed to printing.

M. Morvan exhibits maps, writings, and pen-drawings, photographic proofs, &c., copied by this process, which seem to demonstrate that the process is a valuable improvement.—*Cosmos.*

International Exhibition, 1862.—*Jurors' Report.*

From the Lond. Civ. Eng. and Arch. Journal, Nov., 1862.

CLASS VIII.—MACHINERY IN GENERAL. *Subdivision II. Separate Parts of Machines, Specimens of Workmanship, Miscellaneous Pieces of Mechanism.*

(Continued from p. 180.)

SECTION I.—*Heavy Castings or Forgings in the Rough; Castings or Forgings, plain, intricate, or beautiful, in the rough.*—As compared with articles under these heads exhibited in 1851, we consider there is a decided improvement; few, however, are exhibited in this class as abstract specimens, but are for the most part portions of machines: there are nevertheless some excellent specimens of forgings of very large dimensions, and which owe their excellence in finish and soundness, mainly, to the facility afforded in their construction by the application of the Nasmyth and other steam hammers: some of the large forged shafts are put together in longitudinal segments, which is another reason for their soundness. A complete revolution in the manufacture of large forgings has been effected by the steam hammer. The castings of large marine engine cylinders and other parts, the crank shafts, cross-heads, connecting rods, &c., in wrought iron, as shown in the present Exhibition, are such as never were produced of equally good quality on any former occasion.

Fr. Krupp, Essen (Prussia—1308).—This exhibition includes the largest block of steel in the Exhibition; also some excellent specimens of cast steel axle-trees, and other first-rate specimens of steel manufacture. Medal awarded for excellent workmanship and material, practical success, general excellence.

Höder Mining and Forging Company (Prussia—1258).—Wheel forgings, locomotive tires of puddled steel, wrought iron telegraph poles, &c. Honorable mention, very good work.

Petrarsa Royal Works (Italy—1058).—A large wrought iron shaft for screw propeller, very good specimen of plain forging. Honorable mention.

Under the above heads, the Jury wish to call attention to a beauti-

fully forged and finished cross-head for a marine engine, being one of a pair for the *Agincourt*, 1350 horse power, also a connecting rod of similar powers by Messrs. Maudslay, Sons, and Field. The above is not separately designated in the catalogue.

Also to a double-crank shaft for engines of 1250 horse power, by Messrs. Penn and Son, of Greenwich, excellent both as a forging and a finished piece of work; and to the casting of a cylinder, which is exhibited in the state in which it left the sand, and without having had any subsequent workmanship bestowed upon it. A most beautiful specimen of loam casting. The above are not separately designated in the catalogue.

SECTION II.—*Specimens of Turning in Metals.*—The preliminary remarks of the last section apply with equal force to the different portions of steam engines and machinery in general, inasmuch as by the improved construction of slide lathes planing, slotting, and grooving machines, work is produced of the most superior description.

In the construction of all machines and machinery by the best makers, the great aim evidently now is, to introduce such forms as can be obtained by power tools, without the use of the hand-chisel and file, and the result is, increased elegance and simplicity combined with great economy. It is necessary to point out where these results are most striking, as the awards of the Jurors have already shown their appreciation of them.

One specimen alone of turning and finishing in glass is shown, and this is both practical and new.

J. Chedgey, Southwark (United Kingdom—1820), Glass rollers, pumps, and pipes turned and bored.

New manufacture and good work. The only articles of the kind in the Exhibition. Here is exhibited a household mangle with glass bed and rollers. Medal awarded.

SECTION III.—*Specimens in Filing, and Finished Work in Metals, such as Surfaces, Irregular Figures, &c.*—Broughton Copper Company, Manchester (United Kingdom—1808), Copper and brass work valves, &c., copper rollers for calico printers, and brass tubes for locomotive engines, of very superior quality and workmanship, are exhibited by this firm. Medal awarded.

Eadie and Spencer, Glasgow (United Kingdom—1843), Iron tubes for boilers. Medal awarded for good workmanship.

Imperial Iron Tube Company, Birmingham (United Kingdom—1894), Metal tubes. Medal awarded for good workmanship.

Newton, Keates & Co., Liverpool (United Kingdom—1944), Copper and brass articles for engineers. Medal awarded for good workmanship.

J. Russell and Sons, Wednesbury (United Kingdom—1975), Tubes and fittings, most excellent specimens. Medal awarded for good workmanship.

Stephenson Tube Company, Birmingham (United Kingdom—1994), Seamless metal tubes, rollers, &c. This firm have a most interesting exhibition; and claim great advantages as regards toughness of mate-

rial from the combination of phosphorus in the manufacture of their metal. The Jurors speak in high terms of the whole exhibition. Medal awarded.

A. Everett & Sons, Birmingham (United Kingdom—1848), Brass, copper, and iron articles, tubes, &c. Honorable mention.

Lloyd and Lloyd (United Kingdom—1912), Wrought iron tubes and fittings. Honorable mention. Some excellent specimens of workmanship are exhibited in forgings of wrought iron junctions for gas, having a great number of outlets on the same piece.

Russell & Co., London and Manchester (United Kingdom—1974), Wrought iron tubes, &c. Honorable mention.

SECTION IV.—*Valves, Cocks, Pistons, Governors, Driving Bands, &c.*—Most excellent articles are exhibited under these heads and by a large number of exhibitors. The valves and cocks are both good in design and constructed of materials well suited to the purpose. Metallic pistons are now exhibited having great facility of accurate adjustment against the sides of the cylinders, so as not to cause more friction than is absolutely necessary for preventing the passage of steam, and of very simple construction, and not liable to derangement. Governors are in great variety, but in most cases they partake of the objections to the ordinary ball and pendulum governor, viz: that they do not give a proportionate amount of steam for a varying load, with a maintenance of uniform speed; still in some cases this desideratum is obtained, and the examples are noted and described under their respective numbers. A decided improvement in driving bands is shown, both as regards materials and mode of construction, in leather, india-rubber, &c.

Valves and Cocks.—Raines and Drake, Glasgow (United Kingdom—1788), Engine and boiler mountings. Honorable mention.

J. Beck, Southwark (United Kingdom—1796), Valves and Cocks. These include some very conveniently arranged angle-placed valves as cocks, and the work and finish are very good. Honorable mention.

E. T. Bellhouse & Co., Manchester (United Kingdom—1797), Brass fittings. Honorable mention.

J. J. Silbermann, Paris (France—1162), Air-pump valve. Honorable mention.

F. Allen, Jr. (United States—29), as inventor of slide-valves, valve gear, and expansive gear, exhibited by C. T. Porter. By a peculiar arrangement of levers actuating on a slide cut-off valve at the back of the ordinary steam and exhaust valve, a very simple mode of expansion is obtained with great variation. Medal awarded.

S. Leoni, St. Paul's Street, N. (United Kingdom—1969), Taps, steam-cocks, bearings for machinery. These have not yet been sufficiently tested to prove their superiority, but appear to work with little friction. The substance "Adamas" consists of silicate of Magnesia, calcined, moulded, and baked to any required shape, and appears to possess peculiar anti-friction properties.

Driving Bands.—North British Rubber Co., Edinburgh (United Kingdom—1947), Driving belts, &c. These are said to be very dura-

ble, and have more adhesion than leather. Medal awarded for practical utility and success.

C. A. Preller (United Kingdom—1959), Untanned leather, driving belts, &c. In the leather bands made from ordinary leather, where extra strength is required, this is obtained by one or more thicknesses stitched together; which is objectionable, inasmuch as in passing over pulleys of small diameter the different layers are at different degrees of tension, and increased wear and friction are the result: this is avoided in a great measure in the driving bands exhibited by Mr. Preller, who obtains great increased strength by his peculiar manner of preparing the leather, giving extra strength and suppleness, and thus rendering the double strap in most cases unnecessary, and, when actually required, the objection is not so great as with leather prepared in the ordinary way, on account of the thinness and suppleness of the former. Medal awarded for good workmanship and new manufacture.

Governors.—C. T. Porter (United States—29) exhibits a governor having double-elbow arms, the tendency of which is to raise a weight vertically upon the spindle. This governor is very sensitive, and mainly owes it to rapid rotation, which its peculiar construction requires. Mr. Porter also exhibits another governor, particularly applicable for marine engines; this is also a centrifugal ball-governor, but the centrifugal force of the balls is met by a spiral spring, and is thus described by the exhibitor:—The novel feature in this governor, and that which gives it its value, is the initial compression of the spring: for example, the spring is compressed two inches by the nut on the spindle. The circle in which the centres of the balls revolve is ten inches in diameter, expanding to one of fifteen inches diameter. This expanding motion of the balls produces a further compression of the spring of one inch. The balls are shown in the engraving half expanded, and the spring, if released, would be two and-a-half inches longer than it appears. It will be observed that the expansion of the balls adds fifty per cent. to the diameter of the circle which they at first described, and also fifty per cent. to the original compression of the spring. If, therefore, the centrifugal force of these balls and the resistance of the spring are in equilibrium in any position, they will be so also in every other position, the number of revolutions per minute remaining the same. The resistance varies, by the increase or decrease in the compression, precisely as the force varies by the expansion or contraction of the circle.

Farcot and Sons, Port St. Owen (France—1152), Governors with crossed arms, arranged so as to overcome in some measure the objection to the ordinary ball-governor, by making it more accurate for varying amount of load upon the engine. Medal awarded.

A. B. Albaret & Co. (France—1207). This consists of a fly-wheel mounted on a movable centre, which enables it to be set at different angles with regard to the line of its own axis: when revolving, the tendency is to move to a position at right angles with its axis, and in so doing to act up the throttle-valve.

M. A. Soul (United Kingdom—1992) exhibits a governor which may be thus described:—A fly-wheel having a long boss with a spiral groove cut in it, is placed upon a hollow spindle with a straight groove in it; inside said spindle is another which carries a pin as a driver to the fly-wheel; if the spindle or shaft overruns the fly-wheel, the interior spindle is moved in or out as the case may be, and the movement is communicated to the throttle-valve.

Schiele's governor, exhibited by the North Moor Foundry Company (United Kingdom—1948), acts by water-pressure upon a piston, given by a centrifugal pump. This governor can be made to exert great force, so as to be capable of acting directly upon the sluice or clow of a water-wheel or other large valve; under ordinary circumstances where great sensitiveness is required, an elastic diaphragm may be used instead of a piston.

J. Hick, *Reporter.*

(To be Continued.)

Aluminium Bronze

From Newton's London Journal, September, 1863.

The important part which the new metal, Aluminium, appears destined to play in the arts, chiefly as an alloy, induces us to direct the attention of our readers to the peculiarities of aluminium bronze, which, if considered both in respect of its characteristics and its market value, will be esteemed by manufacturers virtually a new metal.

When the French chemist, M. Deville, published, in 1854, an account of his experiments upon the preparation and properties of aluminium, great hopes were entertained that it might be produced at a sufficiently low price to admit of its receiving many practical applications, to which it seemed suitable on account of its remarkable qualities. A metal, being but little more than one-third of the specific weight of copper, and considerably less than half that of the lightest of the commercial metals, zinc; unacted on by oxygen or sulphur, and but little affected by most acids; possessing at the same time tenacity, combined with ductility, and having a moderately high melting point,—might well be supposed, *à priori*, to be susceptible of many interesting and very important uses. Up to the present time, however, these expectations concerning aluminium have not been realized. Although it is now produced on a considerable scale, the price remains too high* to permit of its being put to many uses to which it might be applied if it were a cheap metal; and its peculiarly dull color is an impediment to its employment where beauty and brilliancy of appearance are desirable. Independently, however, of its usefulness *per se*, there seems to be a wide field open for the application of aluminium in the form of alloys with the more ordinary metals, the properties of which are changed in a remarkable manner by its presence, even in small quantities. On the other hand, very small quantities of the common metals destroy the ductility and malleability of aluminium itself—in

* The present price in London is about 5s. per ounce.

some cases altering its color, and, in others, rendering it as brittle as glass: mixed, however, with a certain proportion of copper, an alloy is produced which possesses the properties of a valuable metal, capable of applications not only very important in themselves, but for which it seems difficult to find any other metal or metallic alloy equally suitable. This mixture of aluminium and copper is the alloy called aluminium bronze. The alloy seems to have been first made a few years ago by Dr. Percy. Many of our readers will remember the specimens which were placed in the International Exhibition by Messrs. Bell, of Newcastle; and a later exhibition of articles manufactured from this substance by Messrs. Mappin, of Regent-street, must have familiarized most persons with its fine general appearance. Beauty of external appearance, however, is but one quality of a metal, and although an all-important one, in certain respects, it is one without which, as in the instance of iron, the metal may possess the most valuable and interesting properties. Without beauty of surface, it is true that its applications must be limited to be useful; but in England, where the employment of metallic substances is so varied and so extensive, mere beauty is a secondary consideration. In the case of aluminium bronze, however, beauty of exterior and more sterling qualities are united. In color, this alloy resembles gold so close, that it would be difficult by mere inspection to distinguish one from the other; but its mechanical qualities excel those of gold. It is composed of copper and about 10 per cent. of aluminium melted together, and re-melted once or twice. It is stated that the most essential condition to success in producing the alloy is purity in the copper employed; the best copper for the purpose, although its price prevents it from being much used, being that deposited by galvanic action: the next best is that from Lake Superior, which is very pure, and yields, with aluminium, a very good alloy. The re-melting of the alloy is a matter of great importance. The first melting appears to produce intimate mechanical mixture, rather than chemical combination of the metals; as in the proportion of 10 of aluminium and 90 of copper, an alloy of a very brittle character is produced by the first melting; but renewed opportunity of uniting into a definite chemical compound being afforded by repeated melting, a more uniform combination seems to take place, and a metal is produced free from brittleness, and having about the same degree of hardness as iron. The alloy containing rather less than 10 per cent. of aluminium, is said to possess the most uniform composition and the best degree of hardness; but it is not always an easy thing to produce this desirable uniformity of texture; as patches of extreme hardness sometimes occur, which resist the tools and are altogether unamenable to the action of the rollers. The alloy produced by this combination of copper and aluminium is very tenacious, malleable, rigid, light in weight, and possesses a fine golden color. Its qualities being so various, we have to view it in two different characters, viz: as suitable to the manufacture of ornamental articles, to which it is adapted from the closeness of its resemblance to gold; and as capable of being applied, on account of its valuable mechanical pro-

perties, to useful purposes, to many of which it seems to be better fitted than any other metal or alloy.

With regard to the first, but what is really, after all, the least important of its characters—that is, its adaptability to ornamental uses—the points to be considered are: color, condition of surface, capability of receiving impressions from dies, or being worked and chased, and, lastly, insusceptibility to the action of oxygen and sulphur. What is the situation of aluminium bronze with reference to these questions? In its application to ornamental purposes, this alloy is, undoubtedly, a valuable addition to the resources of the artist, inasmuch as it affords him the means of imitating almost exactly the effect of gold, in a material very superior to the ordinary gold substitutes, homogeneous in texture and color, and comporting itself, with respect to external influences, more like silver than like a cheap alloy. In sculptured and chased work, it presents a similar depth and richness of effect with gold, and in polished surfaces it is almost equally brilliant; whilst, in cases where it is thought that the color of the alloy does not afford a sufficiently close approach to the tint of pure yellow gold, it will probably, as a gilding metal, present the best possible foundation for a coating of fine gold.

In many respects, therefore, the new alloy may be reasonably expected to play an important part in relation to ornamental work. It remains to examine its qualities with regard to important mechanical applications, and it is here that the valuable qualities of the alloy come out in the strongest manner. In respect to this part of the subject, the properties of the metal to be considered are its tenacity, malleability, power of resisting compression, rigidity, founding qualities, behavior under the action of tools, and specific weight. With regard to most of these points, the aluminium alloy compares with great advantage with all other metals and alloys. In experiments made in the Royal Gun Factory at Woolwich, by Mr. Anderson, upon the tensile strength of this metal, he found it to exceed that of the best gun metal in the ratio of 2 to 1; the aluminium bronze sustaining a strain of 73,185 pounds to the square inch, the gun metal not more than 35,040 pounds; whilst the tensile strength of the best cast steel is about 72,000 pounds. So with regard to the power of resisting compression, it was found that a specimen of the alloy bore a crushing force of 132,000 lbs. per sq. in., whilst there were no indications of compression until 20,384 lbs. per sq. inch had been applied; the strength of the alloy under compression exceeding that of the best cast iron, which may be taken at less than 120,000 pounds. The superiority of the metal extends likewise to the question of transverse strength or rigidity, wherein it surpasses gun metal in the ratio of 3 to 1, and brass in the ratio of 44 to 1. As a founding metal it can be employed without difficulty, and it produces castings, of any size, of the best character; whilst under the file, and in the lathe, it can be worked almost as easily and freely as gun metal. Although it can be rolled into sheets, it is said that it does not solder very readily nor strongly, and this might perhaps prove some impediment to its use in producing certain

forms of work. But in every other respect ordinary mechanical manipulation can be applied to it with the greatest success.

There is an important quality of the alloy not yet mentioned, that is, its low specific gravity. The weight of the bronze, containing 10 per cent. of aluminium, is 7·68, a weight which corresponds very nearly with that of wrought iron; so that, taking into consideration the superior strength of the material, and the consequent smallness of parts necessary in an apparatus constructed from it, we perceive that, from the lowness of its specific gravity, the work would be extraordinarily light. Altogether, in a mechanical sense, this alloy seems to compare most closely with steel; and it is the opinion of competent persons, that in certain kinds of apparatus and instruments, the oxidizable steel may be well substituted by the comparatively unoxidizable aluminium alloy. It is probably in the construction of high-class philosophical apparatus, therefore, that the great value of this alloy will be found. In such work, combined strength and lightness are requisite, and these qualities are united in the highest degree in aluminium bronze. It can be engraved with great sharpness and regularity, and the engraved lines are said to be remarkably distinct. Writing on this subject, Lieutenant-Colonel Strange observes, that experiments, and the concurrent testimony of those who have given it a fair trial, prove that 10 per cent. aluminium bronze is superior, not in one or some, but, in every respect, to any metal hitherto used for the construction of philosophical apparatus.

The present price, about 6s. 6d. per pound, of the alloy, is no doubt an obstacle to its extended use. In cases where elaborate workmanship is required, the price will, however, bear but a small proportion to the value of the work; and the important question, under such circumstances, is not the difference of a few shillings in the value of the raw material, but the existence of qualities in that material which will ensure the greatest possible effectiveness in the manufactured article.

Proceedings of the Association for the Prevention of Steam Boiler Explosions, Manchester.

From the Journal of the Society of Arts, Nos. 536 and 543.

[Extracts from the Annual Report for 1862, of the Chf. Eng'r.]

It appears that all the boilers under the care of the Association have received their full complement of examinations during the past year, including an annual visit of inspection from the chief engineer; while the report goes on to say, "820 of these boilers have been examined 'Thoroughly,' that is, when empty and cold, when the inspector not only gets inside them, but also goes up the flues, so as to ascertain the condition of the plates and seams of rivets throughout. The number of these 'Thorough' examinations this year is higher than it has been in any preceding one since the commencement of the Association, and it is nearly double that of last year." In consequence of this increased number of "Thorough" examinations, it was stated that a larger number of defects than usual had been revealed, and

which would otherwise have been unknown; an additional illustration of the importance of these "Thorough" examinations. "The defects discovered in boilers are mainly of two classes, one relating to their construction and the other to their condition. Under the first head, namely, that of construction, 196 recommendations had been made, which are as follows:—

"In 153 boilers the internal flue tubes have been recommended to be strengthened by hooping.

"In 18 boilers the shells have been recommended to be strengthened at the steam domes by stays of angle iron, &c.

"In 9 boilers the shells have been recommended to be strengthened at the ends.

"In 16 boilers the loads on the safety valves have been recommended to be reduced."

Under the second head, namely, that of condition, 85 defects had been discovered, all of which were considered dangerous; they are as follows:—"Fracture of plates and angle irons, 13; blistered plates, 1; furnaces out of shape, 12; corrosion, 37; defective safety-valves, 5; defective water gauges, 9; defective blow-out apparatus, 7;" others, not actually dangerous, but still unsatisfactory, were then given, which need not here be repeated. The report then went into a detailed consideration of the defects discovered under each of the above heads; some of the remarks on corrosion may be given.

"Corrosion is found to be going on in all boilers more or less, and it will be seen that the greatest number of dangerous defects in the preceding table are to be found under this head.

"In one case a boiler set upon a mid-feather wall 15 inches thick, had a channel eaten right along it about 8 inches wide, which ran down the centre of the seating, while the plates at the edges of the brick-work appeared quite sound, and the danger consequently passed for some time unsuspected. In a second instance, with a mid-feather two feet wide, the plate was found to be eaten almost through from nearly one end of the boiler to the other—while in a third, where lime had been allowed to come in contact with the boiler at the mid-feather, the plate was completely pulverized, and could be carried away in handfuls. In a fourth case, a vertical tubular boiler had been placed close to a wall, one part being in actual contact. Damp in the brick-work set up corrosive action in the plate, which being concealed by the position, went on undetected until the metal was completely eaten through, and a piece blown out by the pressure of the steam. The original plating of the boiler was thick, the pressure low, and the corrosive action local, only affecting a surface of about 12 inches square, so that the rent did not extend."

"Examples of corrosion might be multiplied indefinitely; enough, however, has been said to show the importance of having all parts of the boiler accessible to examination, the flues sufficiently capacious, and the seatings as narrow as possible, and also of having the brick-work removed occasionally, at all events in places, so as to ascertain the condition of the plates, since to conclude that the parts concealed

are in the same condition as those in view has been found in practice to be fallacious."

Under the head of Explosions it was stated:—"It is to be regretted that no means exist of ascertaining the whole number of steam boiler explosions that occur in the United Kingdom, and there can be no doubt that many are not recorded at all. There are known, however, to have occurred during the last year, no less than 31 explosions, from which at least 87 persons have been killed, and 88 injured. Of the number of lives lost by some of the above, no account could be obtained; while from one of them as many as 29 persons were killed and 12 injured; from a second, 12 were killed and 24 injured; and from a third, 6 were killed and 8 injured."

"The following list gives the description of boiler to which the explosions have occurred, with the number of each class, as well as of the persons killed and injured:—1 Haystack Boiler, 12 persons killed and 5 others injured; 6 plain cylindrical egg-ended boilers, 6 persons killed and 6 others injured; 3 iron work boilers, 47 persons killed and 44 others injured; 3 plain single-flued Cornish boilers, 2 persons killed and 2 others injured; 2 plain double-flued Lancashire boilers, 4 persons killed; 3 locomotive boilers, 4 persons killed and 2 others injured; 1 agricultural boiler of tubular portable construction, 4 persons killed and 4 others injured; 1 kitchen-range boiler, 1 person killed. Also 8 other boilers, of the construction of which no reliable information could be obtained, but from the explosion of which 27 persons were killed and 22 others injured."

An analysis of the causes of explosion then followed, the summary of which is as follows:—"Of 31 explosions which have happened during the year 1862, 11 occurred to externally fired boilers, from failure of the plates exposed to the action of the fire; 3 resulted from internal corrosion, and 3 from external; in addition to which, 4 were due to improper original construction, one to shortness of water, and another to accumulated pressure through want of a safety-valve; while 7 occurred at a distance which precluded a personal investigation of their causes, at the same time that no reliable information could be obtained with regard to them."

It was also stated that since the foundation of the Association eight years ago, "It has been found, upon limited inquiry only, that throughout the United Kingdom no less than 213 explosions have occurred, which have been attended with the loss of 472 lives, in addition to serious injury to 512 persons, and considerable damage to property."

Proceedings of Meeting Feb. 20, 1863. *Report of Chf. Eng. from January* 1*st to February* 20*th.*

Explosions.—Another death has resulted from the explosion which occurred to the iron works' boiler referred to in the monthly report for December last, thus making in all 11 deaths from that single explosion, while, in addition, 25 persons were injured.

Three explosions* have been reported since the commencement of this year, from which, however, no lives have been lost, nor any personal injury done worth mentioning. Not one of the boilers in question was under the inspection of this Association. The following is a tabular statement:—

From January 1st, 1863, to February 20th, 1863, inclusive.

Index No.	Date.	General Description of Boiler.	Persons killed.	Persons injured.	Total.
No. 1.	Jan. 12th.	Ordinary double flue, or "Lancashire." Internally fired, .	none.	none.	none.
No. 2.	Feb. 6th.	Plain Cylindrical. Externally fired, .	"	"	"
No. 3.	Feb. 7th.	Plain Cylindrical. Externally fired. .	"	"	"

No. 1 Explosion.—There has been no opportunity of investigating the cause of this explosion, neither have any reliable reports been obtained, but with regard to Nos. 2 and 3, a personal examination has subsequently been made of the boiler in each instance.

No. 2 Explosion.—The boiler in this case was externally fired, and of plain cylindrical construction, the ends being slightly domed. The length was 5 feet; the diameter, 2 feet; and the thickness of the plates $\frac{3}{8}$ths in the ends, and $\frac{1}{4}$ in the remainder. The cylindrical portion of the shell was composed of two plates, about three feet wide, laid lengthwise, and flanched at their attachment to the end plates, which were in one piece. The complement of fittings was most incomplete, the number of those omitted being greater than those supplied. There was no feed stop-valve, no feed back-pressure valve, no steam pressure-gauge, nor any tap for applying the indicator as a test of the actual pressure. The only fittings were, one glass water-gauge, and one safety-valve, the latter stated to have blown off at a pressure of 25 lbs. to the square inch.

The boiler had lately been purchased second-hand, and not put into regular work since its re-setting. In consequence of this, the feed-pipe was not yet connected, and the boiler had been supplied with water poured in by hand at the safety-valve when the steam was down. The engine was standing at the time of the explosion, but had been working about an hour previously.

The results of the explosion to the surrounding property were, that the workshop in which the boiler was set was laid completely in ruins, the chimney leveled to the ground, and the windows of a house on the opposite side of the street broken by the concussion. The boiler was rent into five pieces, one of which was blown across the street, and lodged upon the top of the opposite house, while the manhole cover was thrown upon the roof of a shed in another direction.

With regard to the cause of the explosion, the primitive mode of feeding the boiler naturally excited suspicion as to the sufficiency of

* Since this was in type, another explosion of a very fatal character has occurred. Engineering particulars as to the construction of the boiler and cause of the explosion will be given in the next monthly abstract, the explosion having happened on February 23d, while the present report closed on February 20th.

the supply of water; and with this view, therefore, a particular examination was made of the remaining fragments of the glass water-gauge, the color of the plates, and the position of the fracture; in addition to which, the circumstances attendant on the working of the boiler were inquired into. The result of this investigation was, that shortness of water did not appear to have been the cause of the explosion, and this conclusion was corroborated by further examination, as will be seen from the following particulars.

The safety-valve, which was supposed to have blown off at 25 lbs. pressure, was found, on investigation, to have been loaded to upwards of 100 lbs.; the diameter being one inch, the proportions of the lever thirteen to one, the weight at the end 5 lbs., in addition to that of the lever itself. It is impossible to say, however, whether the valve had been free or not, since it, as well as the lever, had been blown away; and as there had been no steam-gauge, the pressure must always have been a matter of uncertainty, and thus it can only now be concluded that 100 lbs. on the square inch was the minimum.

A boiler, however, of such dimensions as the one in question would, if well constructed, withstand a much higher pressure than that of 100 lbs. per square inch; but, in this case, the manhole had not been strengthened with any mouth-piece, and consequently made a very weak point in the shell, from which the explosion appeared to have arisen. Five rents had started from it, while the remaining fractures were all subsidiary to these, and nothing more than the simple development of them.

The effect of the manhole would be to throw upon the plates of the shell, in the immediate vicinity of the opening, an extra disruptive strain of about 10 tons, added to which, the cover being an internal one, there would be acting upon it an upward pressure of steam amounting to about five tons, and tending to drive it through the manhole. The cover was a bad fit, being much too rounding, in consequence of which difficulty had always been experienced in making the joint, and it had been severely tightened by a stout bolt, which left the impression of the heels of the bridge in the plates. When it is remembered that the thickness of the plates was only $\frac{1}{4}$ of an inch, it will not be thought surprising that fracture should have occurred at the manhole, under the above circumstances; and the fact of five of the rents emanating from this point, and all the others being explicable upon the view that fracture commenced there in the first instance, it is thought to be conclusive that the mal-construction of the boiler, in not being suitably strengthened at the manhole, was the cause of the explosion.

The proprietor of this boiler had just purchased it, in addition to a small engine, with a view of increasing his business, but has not only lost the savings he had thus invested, but involved himself with regard to the surrounding property; an illustration of the false economy too frequently practised with regard to boilers, as well as of the risk to which lives may be exposed, though unintentionally so, when as in the present instance, such ill-appointed boilers are worked in the heart of a populous city.

No. 3 Explosion.—The circumstances in this case were very similar to those in No. 2. The boiler was externally fired, and of plain cylindrical construction. The length was 7 feet 6 inches; the diameter 3 feet; while the plates varied in thickness from $\frac{5}{16}$ths to $\frac{1}{4}$. The boiler was made out of an old flue-tube taken from an internally fired boiler, and the longitudinal seams were in line. The fittings consisted of only one float, and one safety-valve, there being as in the previous case, no steam-guage, nor any means of ascertaining the actual pressure. At the time of the explosion the engine was not at work, but the steam was being got up in preparation for starting, and the boiler was stated to have been amply supplied with water, which an examination of the plates and fractures, afforded no reason to doubt.

As to the cause of the explosion, there could be no room for hesitation. The safety-valve, which was stated to have blown off at 50 lbs. pressure, proved to have been actually loaded to upwards of 200 lbs., the diameter being only three-quarters of an inch, the proportions of the lever, seven to one, and the weight with which the lever was loaded, 21 lbs. The manhole in this boiler, as in the previous one, was not strengthened by any mouth-piece, and the rents, as before, had started from this opening.

Attention has already been called in these reports to the weakening effect produced upon the shells of boilers by unguarded manholes, as well as by openings cut in the plates at the base of steam domes, and a case of explosion from these causes previously recorded.

All modern well-appointed boilers have, as a rule, their manholes strengthened by strong mouth-pieces riveted to the plate, the surface for the cover-joint being faced; still, it is thought that the weakening effect produced upon the shells of boilers by steam domes has not, as yet, received sufficient attention, and although it may have proved hitherto comparatively harmless, that the gradual increase of pressure, now generally taking place, must shortly force the subject into notice, and thus prominence is given to the details of these two explosions with a view of showing the importance of the subject. The danger of working without steam pressure-gauges will also be apparent from both of the above explosions.

The results of this explosion were curious rather than serious, and attested the force of atmospheric concussion produced by steam. A dwelling house directly facing the boiler, and situated about 50 feet from it, had its four windows, two on the ground floor and two immediately over them, all dismantled. A shower of bricks had been projected through the lower window immediately opposite the boiler, and had left their scars upon the walls of the room inside, while the two upper were also blown in. This will not excite much surprise; but the other lower window was stated not to have been blown in, but drawn out, and this was attested by the debris of the sash lying upon the ground in the yard, while it was added that a looking-glass standing in the room had been sucked out along with the window-sash, and thrown upon the ground outside.

The same apparent anomaly has been noticed with regard to explosions caused by gunpowder, some objects being thrown away from the seat of the explosion, and others drawn towards it. This is accounted for by the double action that takes place; namely, first an expansion, which causes pressure, and then a recoil, which produces exhaustion. Some objects are more susceptible to the effect of pressure than exhaustion, while others are the reverse, and each succumbs to that action to which it is able to offer the least resistance. Thus unguarded windows fall under the first action—viz; that of pressure consequent upon the expansion, while outside shutters, adapted to resist external aggression, withstand the former, but yield to the exhaustion consequent upon the recoil.

There were further signs on the roof of an adjoining shed of the force of atmospheric impact, consequent on the explosion. This shed stood at right angles with the dwelling-house, and extending toward the seat of the boiler, formed, with the buildings immediately adjoining the latter, nearly three sides of a square. A considerable portion of the side of this shed nearest the boiler was open, while the other sides were closed. The effect upon this shed was, that many of the stone flags, with which the roof was covered, were blown up, and, clearing the pegs which hung them to the rafters, slid down upon the lower ones, while others mounted the rafters only and there remained. The portion of the roof affected was the side of the gable opposite to the open doorway, and most distant from the boiler, since that side presented a surface more nearly at right angles with the direction of the impulse than the other. These particulars, though not important in themselves, afford, it is thought, additional evidence of the high pressure at which the boiler must have been worked.

In conclusion, no cases of such excessive pressure, as those given in the report above, have ever before come under my observation; and I trust that it will be seen, from the results which followed, what an engine of danger an ill-appointed steam boiler may become; and also how seriously the shells of boilers are weakened by gashes cut in their plates, either at manholes when unguarded by substantial mouthpieces, or at the base of steam domes; and I would recommend that all boilers should be fitted with a steam pressure-gauge, and those working separately, with a duplicate safety-valve.

The Electro-magnetic Phonoscope.

From the London Builder, No. 1067.

A musical machine, for registering music instantaneously as played, has been invented by Mr. J. Beverley Fenby of Bute Villa, St. John's, Worcester, according to the local *Herald*. The machine is small, and its motive power is electro-magnetic, produced by a voltaic battery, and working in a manner analogous to the printing telegraph. The machine having been placed *en rapport* with the instrument to be played upon, say piano-forte, harmonium, or organ, the player manipulates the keys in the usual manner, and the machine prints his per-

formance as he goes along, at a speed proportionate to his playing, the usual rate being 15 inches of paper per minute. The printed notation is identical with that already in use, the only difference being that the heads of the notes are square instead of round. The printing, adds our authority, is clear and well defined, and the performer feels not the least impediment or hindrance to his playing from the machine, however rapid or complicated his ideas may be. The performer may compose, play, and print at one and the same time. The patent for this invention has just passed the Great Seal. A similar instrument was noticed in the *Builder* not long ago.

For the Journal of the Franklin Institute.

A Dictionary of Mechanical Fallacies.

Circumstances have lately revived an old resolution that I would suggest a remedy, if I did not attempt to provide one, for an evil to which an eminently meritorious class of men have long been exposed, and now more than ever. Among other cases, I have been asked by a friend, previous to his investing funds to carry out the project, what I thought of the propulsion of vessels by the re-action of *air* forced into the water: would it be more efficient than the old plan of using water as a propelling agent, and would it be likely to supersede propelling blades? The answer was, that any principle not found working in nature would be found worthless in art; that if the ejection of air against water can propel a ship, so might water forced against air; that the highest speed obtained by forcing out water under the stern, compared with the effect of paddle wheels, relatively that of slow contrasted with quick moving fishes; and that if air were substituted for water, the comparison would be between the progress of the mussel or clam and that of the mackerel or dolphin. The enthusiastic projector thought he had got hold of an idea both new and of great practical value—a double mistake.

With the view of calling attention to the subject, I beg to remark that the labors of unsuccessful inventors have an indirect or negative value, and ought not to be consigned to oblivion. If they do not point out right paths, they do the next best thing by showing which are wrong ones. What few persons surmise, these men have furnished and continue to furnish materials for a book, which, if it were printed, would never cease to be consulted, and never without profit. It is next to impossible for an inventor to know all that has been attempted in the line of his pursuit. Were he to consult the thousands of volumes that have been written on the Arts, and the Transactions of all Societies of Arts, there would be legions of devices unnoticed. He wants to be informed of plans that have failed as well as of such as have succeeded. It is for lack of this information that antiquated devices are being constantly revived and sent to the Patent Office. How is this swelling evil to be arrested—this loss to society of misapplied labor, intelligence, and money; attended, too, with bitter pangs of individual disappointment and sometimes of despair? I

have often thought, only by *a Dictionary of Mechanical Fallacies, including superseded devices.* As a work of reference it could never become obsolete. In every decade it would save hundreds, if not thousands of ingenious men from wasting their energies and means on worthless, and too often, on irrational projects. I question whether a book of equal and equally enduring practical value can ever be added to a publisher's stock.

As long as inventors are led, as by instinctive impulses, into the same trains of thought—that is, while the human mind is constituted as it is, a work of the kind will be called for. In bulk it need not exceed a stout octavo. Its descriptions may be both brief and clear. In many, if not most cases, three lines would suffice. It will admit new items, but will part with none, old or new. Let no person object to such a compilation that it will open a barren field of inquiry. Useful suggestions will be inseparable from the act of consulting it. But passing that, a volume designed to prevent, and which would assuredly prevent ingenious men from attempting things that can only end in discomfiture, and from cherishing hopes most certain to be crushed, is a real desideratum. E.

New York, Oct. 11, 1863.

Another New Metal.—Siderium.

From the London Builder, No. 1065.

The new metals, we suppose, are envious of the new asteroids, and are doing their best to keep pace with them in revealing themselves to modern science. Another new metal has just been discovered. In the development of his invention for the production, on a commerical scale, of the metal magnesium, which it is hoped will at no distant period be extensively used as a substitute for silver, Mr. E. Sonstadt, of Loughborough, has, it is said, discovered a new metal in the "carcasse" remaining when the chloride of magnesium is obtained by evaporating and igniting the chlorides of magnesium and sodium. In many of its reactions this new metal corresponds almost precisely with iron, for which metal it has probably hitherto been mistaken. The new metal appears at present, to occur invariably in connexion with magnesium, which cannot be entirely freed from it.

Table for Finding the Diameters of Shafts of Wrought Iron.

From the London Artizan, Sept., 1863.

The want felt in the drawing offices of engineers and machinists, of a ready means of determining the diameter of shafts suitable for transmitting a given power, has often been stated to us; and having been recently requested to furnish information on this subject to several correspondents, we have much pleasure in being able to present our subscribers with the accompanying table, which has been obligingly furnished to us by Mr. W. Jackson, of the firm of Jackson & Watkins, of the Canal Iron Works, Millwall.

This table exhibits a set of curves giving the diameter of shafts, in

inches, for engines of from 10 to 500 horse power, the revolutions varying from 20 to 150. This table was computed from the formula—

$$D = \sqrt[3]{\frac{320 \text{ H. P.}}{n}}$$

D being the diameter of the shaft,
H. P. the horse power,
n the number of revolutions per minute.

Example.—Required, the diameter for the driving shaft of an engine of 260 horse power, making 30 revolutions per minute. By the table D = 14 ins. Intermediate powers or speeds may be ascertained by interpolation, for example, 250 H. P. at 30 revolutions = 13·8 ins.; or 260 H.P. at 32 revolutions = 13·8 ins.

For the Journal of the Franklin Institute.

On a New System of Arithmetic and Metrology, called the Tonal System. By JOHN W. NYSTROM, C. E.

(Continued from page 275.)

The inconvenience of our many different systems of metrology is well known and complained of by all civilized nations. The objections are not confined to complicated calculations called compound arithmetic, which is to reduce long series of values to the lowest unit by multiplication and addition to render the principal calculation practicable, and then reconvert the resulting amount to the original series of units, by division and subtraction; but very often one is wholly at a loss to know what to do, for want of a knowledge which cannot possibly be stored in one's mind. Most civilized nations have, for centuries back, endeavored and are now endeavoring to improve their systems of metrology, but the common difficulty met with, is the unnatural decimal base *ten;* when that base is changed, then, and *not until then*, can we expect a satisfactory system of metrology and calculation.

Examining the different tables of weights and measures of different countries, we find that the units are almost invariably divided by numbers of the following series, 8, 12, 16, 24, 32, 36, 48, 96, &c., &c., that although our arithmetic is based on 10, not one system of metrology has fallen on that number, save the modern French decimal system, invented by the most celebrated mathematician of the age, now requires an accomplished arithmetician to understand it, and the people prefer to, and do express themselves in the old French system, not that the metrical system is new to them, but because it is unnatural.

In the *Tonal Metrology* all the units are divided and multiplied by the tonal base, and it has become necessary to give new names to the units and their details, in view to establish a universal understanding in metrology.

The tonal unit of length is obtained by dividing the mean circumference of the earth repeatedly by the tonal base, until a length convenient for the shop and the market is obtained. The mean circumfe-

rence of the earth is about 131,216,659 feet, which, divided by 10^7 (1000,0000 tonal) will be 3,489,767,296 parts, each of a length of 0·48882 feet, or 5·86584 inches, the proposed tonal unit of length divided and multiplied by the tonal base, its full length and appearance will be as fig. 1, Plate I. (This figure is drawn on the rule, fig. 3.) Metre seems to be a good and proper name for a unit of length, for which the new unit is proposed to be called the *Tonal Metre*.

TONAL LENGTH.

	Tonal System.		*Old System.*
$\frac{1}{1000}$ metre	=1 mermill	=	0·001432 inches English.
$\frac{1}{100}$ "	=1 mersan	=	0·022913 " "
$\frac{1}{10}$ "	=1 merton	=	0·366615 " "
ONE METRE	=1 the unit	=	5·8658 in. = 0·48882 feet.
10 metres	=1 tonmetre	=	7·82119 feet.
100 "	=1 sanmetre	=	125·135 "
1000 "	=1 millmetre	=	2002·207 "

When the syllable *mer.*—abbreviated from the word metre—is placed before the expression of value, it impresses the mind of a fraction, as mermill $= \frac{\text{metre}}{\text{mill}} = \frac{1}{1000}$ of a metre, and when the expression of value is placed before the unit, it denotes a multiplication of the same, as tonmetre = 10 metres.

The minute measurements, as wire and needle gauges, to be tonally divided and numbered from the metre. The present many confused wire and needle gauges denote the smallest dimensions by the highest number, which ought to be the reverse. Mr. Whitworth has divided the inch into 1000 parts for a wire gauge, and numbered from 1 to 1000 at the full inch; by which the number expresses the true dimension in fraction of an inch, while the Birmingham and other gauges must be accompanied with a table to translate what they mean. Mr. Whitworth has lately proposed the inch as a unit for all measurement of machinery. A measure of 120 inches is 10 feet, which is rather short to be expressed by so many units; it must be translated into feet before it gives a clear impression on the mind; on the other hand, measures of only a few inches, which are very numerous in machinery, cannot properly be expressed in feet; it seems, therefore, that a unit half-way between one inch and a foot, which is the length of the *tonal metre*, would be the most suitable for the shop and the market.

For needle and wire gauges the *merton* should be divided into 100 tonal parts, (256 decimal) or *mermills*, of which each would be about $\frac{1}{4}$ of No. 36 B. W. gauge, or 0·001432 of an inch; this part to be noted No. 1, and the merton would be No. 100, which is about $\frac{3}{8}$ of an inch. Such a gauge would likely be adopted in the shop for minute measurement where the present wire gauges were never known; the very number impresses the mind of the real size derived from the main standard, the circumference of the earth.

The *tonal metre* to be employed in manufactories, for measuring machinery, &c., corresponding to the English foot. The artisan generally carries a two-foot rule, folded into two or four parts, the *tonal* mea-

sure would be of precisely the same shape, but with four units instead of two.

On Plate I. are full size drawings of the *tonal measure*, of which fig. 2 is a four-folded rule of one *metre* in each part, in appearance very much like the ordinary four-folded two-foot rule. The side A A contains the *metre* tonally divided and numbered. The other side B B of the same rule, contains divisions for circumference and areas of circles, arranged so that opposite the diameter on A is the circumference on B and area on C. Suppose the diameter to be 1·16 metres on A, it corresponds with 3·48 metres the circumference on B, and 2·5 square metres the area on C. The small divisions between B and C are each *four metresans* drawn from A to assist the transference and reading on B and C.

Fig. 3 represents a two-folded tonal measure, similar to the English two-folded two-foot sliding rule, numbered and divided same as fig 2. The part E on which fig. 1 is drawn, to receive numbers of specific gravity of substances, and other co-efficients of general use in practice. The scales F, G, and H, are the ordinary sliding rule, divided into the *tonal system*, which in this case stands in such relation to the divisions on the side D D, that any number on H, corresponds with its logarithm on D. The operation on the *tonal* slide rule will be the same as that on the ordinary decimal one.

The clear and simple relation between numbers and logarithm in the *tonal* system has led me to some valuable conclusions in reference to calculating machines, and mathematical instruments, which I believe would be of the greatest service to the world.

The *Tonmetre*, (7·82112 feet) to correspond with the *Fathom*, to be used for measuring ropes, cables, depths of water, &c., &c. The *Sanmetre* (125·135 feet) to be the length of the surveying chain, to consist of 100 (256 decimal) links of one *metre* each.

The *Millmetre* (2002·207 feet) for road measure and distances at sea, correspond with miles; the name would likely be abbreviated to mills, which corresponds with the name of road measure in several languages. One *millmetre* is equal to one *timmill* on the earth's great circle, (see division of time.) Longer distances on the earth's surface would be expressed in *Tims*.

Astronomical distances would be best to express in great circles of the globe, by which the mean distance to the sun would be 8·41 circles. Great distances, such as to fixed stars, could be easier conceived by this measure.

Time and the Circle.

Tonal System.		Old System.
One circle	= 10 Tims	= 24 hours or 360 degrees.
1 Tim	= 10 timtons	= 1½ " 22° 30′
1 timton	= 10 timsans	= 5^{m} 37½^{s}. 1° 24′ 22½″
1 timsan	= 10 timmills	= 21·1^{s}. 5′ 9″
1 timmill	= 1 Millmetre	= 1·31836 seconds. 19·77″

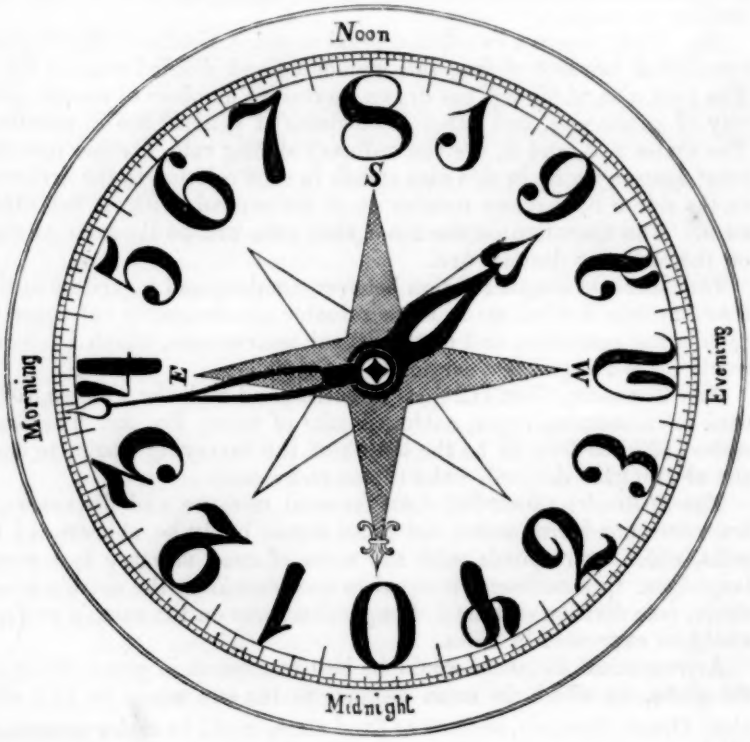
The length of a pendulum vibrating *timmills* will be 8·333 metres = 67·975 inches.

The time, circle, and compass would thus be equally divided, and greatly simplify all astronomical and nautical tables and calculations.

In expressing time, angle of a circle, or points on the compass, the unit *tim* should be noted as integer, and parts thereof as *tonal fractions*, as 5·86 *tims* is five times and *metonby*. The unit *tim* to be pronounced as in the English word *timber*.

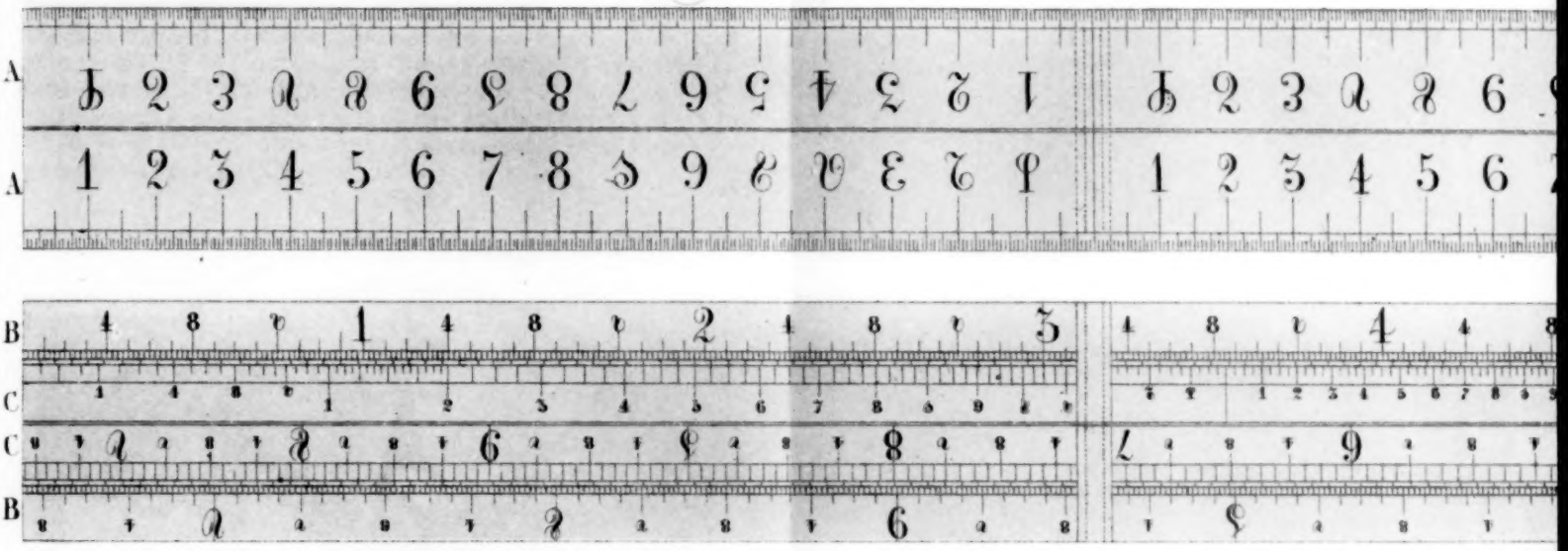
Fig. 4 shows the appearance of a *tonal* clock dial, the time indicated is 9·3ℵ, which expressed by words should be *Kotim* and *titonhu*. The tim hand goes round only once in a night and day, being on 0 at midnight, and on 8 at noon. If a third index hand is added on the

Fig. 4.

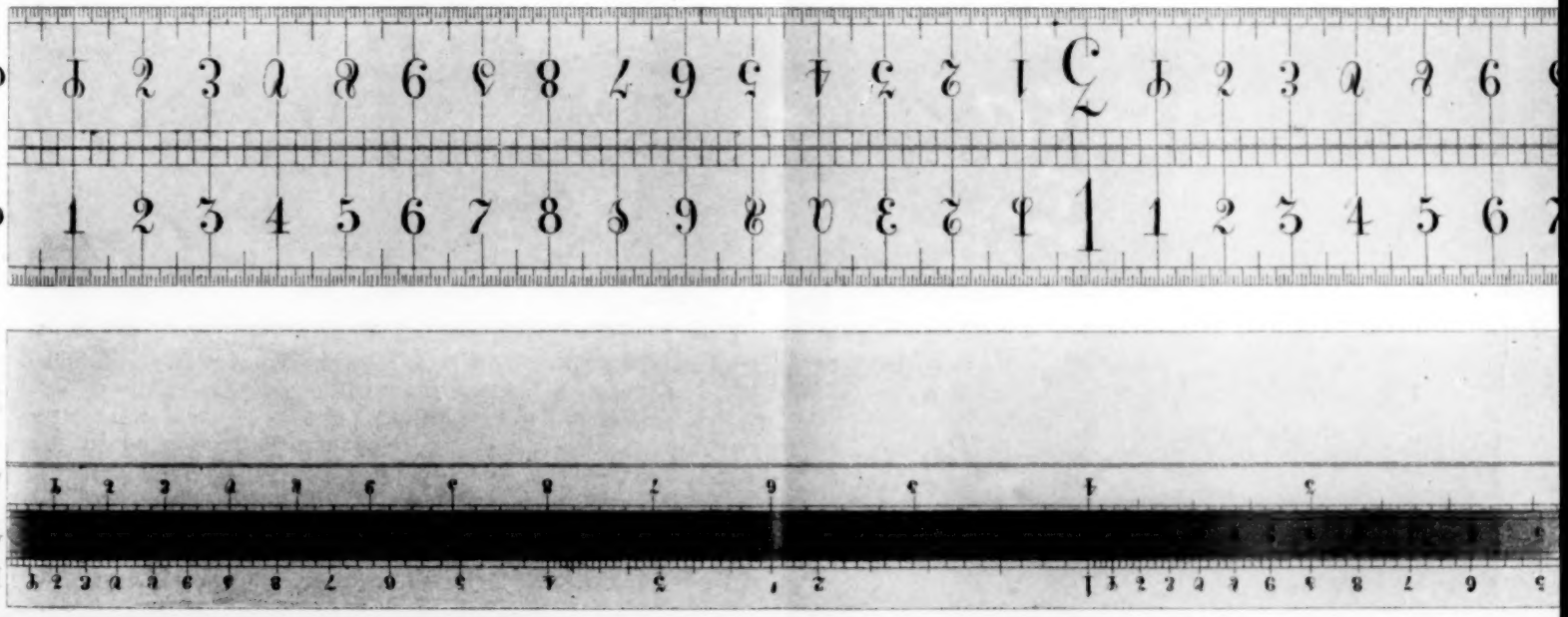


same centre, to represent the second hand on our ordinary watch, it should make one turn on the dial for each timsan, when the small division on the circle would indicate *timbongs* or $\frac{1}{10000}$ part of the *tim*, which is $\frac{82}{10000}$ parts of our present second. Such delicate measures of time are often required in Physical Science, as in astronomical observations, velocity of light and electricity, gunnery, &c. A further extension of delicate measures of time will be conceived in musical vibration, which I shall arrange into immediate connexion with the

Four-folded Tonal measure.



Two-folded Tonal measure.



-folded Tonal measure.

-folded Tonal measure.

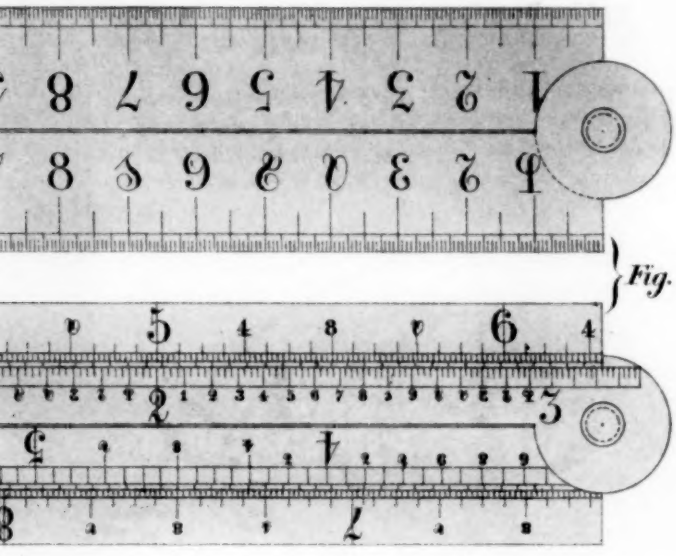


Fig. 2.

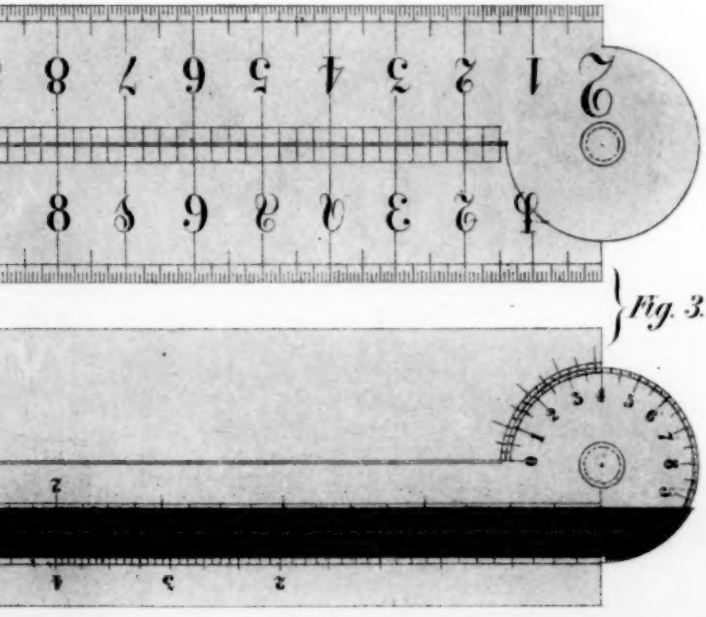


Fig. 3.

tonal watch, that the base-note for the natural key, shall make 10 (16 decimal) vibrations per timmill. Turn yourself towards the south with the *tonal* watch in your hand, and it will be found that the timhand follows the sun nearly; or lay the watch horizontally, so that the timhand points towards the sun, and the figures on the dial will give 0 north, 8 south, 4 east and 0 west, nearly. A very simple table of correction would give the course correctly.

This is easily comprehended by the public, as the *tonal* compass; fig. 5, is divided the same way. A course noted from the *tonal* compass is clear and simple.

Fig. 5.

One *millmetre* in length on the equator corresponds with one *timmill* in time. By this division of time, it is always clear whether it is in the morning or evening, without any special notation. Our present system often leads to error or confusion, whether a noted time is meant in the morning or evening.

Division of the Earth's great Circle.—The latitude should be divided from north to south into 8 *tims*, with 0 at the north pole, 4 *tims* at the equator, and 8 at the south pole. The equator to be divided same as the clock or compass.

Nations ought to agree, to count the longitude from one meridian

drawn through a fixed point on the globe. The different notation of longitude on maps is a great inconvenience and sometimes causes confusion. We often see on maps the longitude is noted, some from Greenwich, some from Paris, Pulkova, Washington, Ferro, and on some maps it is not stated from where the longitude is counted. Independently of the different points from where the meridians are noted, the present divisions of the circle make it very complicated to calculate the difference of time between places, and very few will understand how,—in fact the complication is such as to discourage many persons from the attempt; while if the circle and time were divided as herein proposed, the very figures denoting the meridians would give the difference of time by simple subtraction.

In the Canary Islands appears to be a proper point to place the zero-meridian, as the ancient geographers who have taken their first meridian from the west side of the Island of Ferro 17° 52′ west from Greenwich.

Maps constructed on such principle, would to our descendants forever indicate, not only the true position of the place on our globe, but the scale of latitude would give all distances on the maps in miles (timmills), feet (metres), and inches (mertons), also the area in acres; and a difference of latitude placed along a parallel, would give the correct distance corresponding with time in longitude. Those plain matters are by our present system, not only complicated in calculation, but are seldom thought of, for complication screens away the simple knowledge.

The decimal system is not applicable in dividing the time, circle, and the compass, and consequently cannot be adopted in astronomy, navigation, and geography, which constitutes a most extensive and important part of our arithmetical calculations. The French attempted to divide the day into 10 hours, each hour into 100 minutes, and each minute into 100 seconds, but soon found it impracticable.

Measure of Surface.

Tonal System.		Old System.
One square metre	=	0·239 square feet.
1 Square tonmetre	=	61·15 "
1 Square sanmetre	=	15658·768 "
1000 Square metres	=	0·36 Akres.

The square sanmetre to be the measure of land, corresponding to the acre.

Measure of Capacity.

Tonal System.		Old System.	
1 Gallsan = 10 Gallmills	=	0·79 cub. in.	about a table spoon.
1 Gallton = 10 Gallsans	=	12·62 "	" a tumbler.
1 GALL = 1 CUB. METRE	=	201·78 "	" a gallon.
1 Tongall = 10 Galls	=	1½ Bushels.	
1 Sangall = 10 Tongalls	=	about 30 cub. feet.	
1 Millgall = 10 Sangalls	=	478·2 cubic feet.	
1 Millgall = 1 cub. tonmetre	=	17·75 cubic yards.	

The *Gall* or *cubic metre* to be the unit for measures of capacity, in

ordinary market practice. The *Sangall* to be the measure of excavation and embankments, also for grain, &c. The *Millgall* to be the measure of firewood, being one *cubic tonmetre.*

Measure of Weight.

One cubic metre of distilled water will weigh 7·30174 pounds avoirdupois, to be the tonal unit for weights, and to be called a *Pon.*

Tonal System.			Old System.
1 Ponmill	=		0·02848 drachms avoirdupois.
1 Ponsan	= 10 Ponmills	=	0·45568 " "
1 Ponton	= 10 Ponsans	=	0·45568 pounds "
1 Pon	= 10 Pontons	=	7·3017 " "
1 Tonpon	= 10 Pons	=	116·8 " "
1 Sanpon	= 10 Tonpons	=	1868·8 pounds = 0·838 tons.
1 Millpon	= 10 Sanpons	=	13·34 tons.

The pressure of the atmosphere will be about 46 *pons* per *square metre*, and the height of a column of mercury balancing the atmosphere, about 5 *metres.*

The force of gravity will cause a body to fall 35·217 metres in the first timmill in a vacuum, and the end velocity will be 72·56ƶ metres per timmill.

The *Ponsan* to be the unit for apothecary and minute weights. *Pon* for the ordinary market practice. *Sanpon* as shipping unit and heavy weights, corresponding with the ton.

The decimal system is equally inconvenient in the operation of weighing as for all other measurements; the unit being divided into 10 parts, for which are required five different weights in weighing all the ordinal parts, namely, 1, 2, 3, 5, and 10, or a weight of 4 may be substituted for the 3, but it is, at any rate, an odd and dreary composition of weights.

Decimal Weights.

$1 = 1$ weight.
$2 = 2$ weights.
$3 = 3$ "
$3+1 = 4$ "
$5 = 5$ "
$5+1 = 6$ "
$5+2 = 7$ "
$5+3 = 8$ "
and $5+3+1 = 9$ "

thus all the ordinal parts of 10 can be weighed.

Tonal Weights.

$1 = 1$ weight.
$2 = 2$ weights.
$2+1 = 3$ "
$4 = 4$ "
$4+1 = 5$ "
$4+2 = 6$ "
$4+2+1 = 7$ "
$8 = 8$ "
$8+1 = 9$ "
$8+2 = 10$ "
$8+2+1 = 11$ "
$1+4 = 12$ "
$8+4+1 = 13$ "
$8+4+2 = 14$ "
and $8+4+2+1 = 15$ "

thus all the ordinal parts of 10 (16) can be weighed.

The tonal system also requires five weights, namely, 1, 2, 4, 8, and 10, the most natural composition of weights, they are convenient in the operation of weighing and easy for mental calculation.

It will be observed that the five decimal weights could weigh only the 10th parts of the unit, while the five tonal weights give a nicety of every 16th part; consequently the tonal system has in that case 60 per cent. advantage of the decimal system, and moreover the tonal weights give the natural and desired fractions, quarters, eighths, and sixteenths, which is not the case with the decimal weights.

For the natural fractions it will require three more parts to the decimal weights, namely $\frac{1}{2}$, $\frac{1}{4}$, and $\frac{1}{8}$, or expressed by decimals will be 0·5, 0·25, and 0·125, by which the sixteenth parts can be weighed, but it will be a complicated expression; for instance, 6 parts will be expressed by 0·375 and 7 = 0·4375, which can never be clearly comprehended, because the mind must be carried away to several thousands for only one figure.

The decimal weights cannot avoid the expression of tonal or natural fractions, because they are of daily occurrence in practice; while the tonal system is complete in itself for all uses without exception, and needs no reference to, but will do best without, the decimal system.

If three more parts are added to the five tonal weights, namely, 0·2, 0·4, and 0·8, it can weigh to a nicety of every 128 parts of the unit, the expression will have one decimal (called a tonal) by which the true weight is clearly impressed on the mind.

Measure of Power.—One *pon* lifted one *metre* in one *timmill*, to be called one *effect*. By the present system, *one pound lifted one foot in one second is called one effect*, of which there are 550 effects on one horse-power, or 55 effects on one man's power.

Tonal System.		Old System.
One effect	= 2·704 effects.	
1 man's-power = 10 effects	= 43·268 "	= 0·86 man.
1 horse-power = 10 men	= 692·3 "	= 1·25 horses.

The *man's-power* to be the unit for manual labor, and *horse-power* for machinery and heavy work.

Money.—The American dollar is nearly the mean difference of all the monetary units of the world, and curious enough, compared with the largest, the English pound sterling, £, and the smallest, the French Franc, F, the Dollar, D, will be the mean proportion of the two.

$$\text{L} : \text{D} = \text{D} : \text{F}. \text{ or } \text{D} = \sqrt{\text{L F}}.$$

If the world could agree to adopt one unit for money, it seems that the dollar has a claim to be chosen as a standard.

Tonal System.		Old System.
One dollar = 10 shillings	= One dollar	= 100 cents.
1 shilling = 10 cents	= 6¼ cents.	
1 cent	= 0·39 cent	= 2 centims.

The inconvenience of the monetary decimal system is daily felt in

the actual market practice: for although the dollar is divided into 100 parts, for which suitable coins (most of odd numbers of dollars and cents) are in circulation, the retail prices of most articles are fixed to suit the dollar divided into 16 parts. A drink of almost any description costs 6 or 6¼ cents, which is $\frac{1}{16}$th part of a dollar. A ride in an omnibus costs generally 6 cents. Suppose an article bought for 6 cts., and paid with a quarter of a dollar, there will be 19 cents change summed up by the following coins, 10 ct. + 5 ct. + 3 ct. + 1 ct. = 19 cents. This can reasonably be called an odd system of calculation, because there is nothing but oddity about it. By the *tonal* money, the same article paid by a quarter, which would be 4 shillings, there would be 3 shillings change, in which transaction the mind was carried only to 4, while the decimal money was fumbling about among the odd numbers up to 25.

The natural attempt of dividing the arithmetical base into 16 parts, is shown by bank notes in this country, at 5 dollars, 2½ dollars, and 1¼ dollars. We have 2½ dollar gold pieces, but no 2½ cent and no 25 dollar notes or coin. In fact, our money decimal system is odd and absurd.

	Tonal Coin.	United States Coin.
Copper,	1 cent. 2 cents. 4 cents.	Copper. 1 cent.
Silver,	8 cents. 1 shilling. 2 shillings. 4 shillings. 8 shillings. 1 dollar.	Silver, 3 cents. 5 cents. 10 cents. 15 cents. 20 cents. 25 cents. 50 cents. 100 cents.
Gold,	1 dollar. 2 dollars. 4 dollars. 8 dollars. 10 dollars. 20 dollars.	Gold, 1 dollar. 3 dollars. 2½ dollars. 5 dollars. 10 dollars. 20 dollars.

The *tonal coins* are all of even and of the easiest countable numbers, such as are required in the market, while the *decimal coins* are most of odd numbers, and of a complicated composition for calculation, even the half dollar or 50 cent has a prime number to its index. The *tonal coins* give a nicety of $\frac{1}{256}$th part of a dollar, while the *decimal coins* give it only to $\frac{1}{100}$th part.

The legal interest on money, in most countries, is about 6 per cent., which by the *tonal* system would be nearly 10 per sant; consequently, calculating that interest on money, would be only to point off two figures on the capital.

If the *tonal* interest is 1 more or less than 10 per sant, it is calculated by simple addition or subtraction.

Interest on 3ℰ5ℑ4 dollars at 10 per sant, = 3ℰ5·ℑ4
" " " 1 " = 35·ℑℰ4
" " " 11 " = 3ℓ0·ℰℰ4

which is 3ℓ0 dollars, ℰ shillings, and ℰ4 cents.

This makes a simple interest calculation in the neighborhood where it is most wanted. The difference of 1 per cent. interest in the neighborhood of 6, is a rather large margin, for which we often find it accompanied with a fraction, in practice. One per sant *tonal*=0·391 per cent. decimal. One decimal per cent. is 2·56 *per sant tonal.* Fractions would be rarely required to the percentage in the tonal system.

The most common retail prices of articles in America are as follow:

Market Prices ct.	Tonal Shillings or 16ths of a dollar.	Nearest Decimal Cents.
6¼	1	6
12½	2	12 or 13
18¾	3	19
25	4	25
31¼	5	31
37½	6	37 or 38
43¾	7	44
50	8	50
56¼	9	56
62½	ℑ	62 or 63
68¾	ℰ	69
75	ℓ	75
81¼	ℰ	81
87½	ℰ	87 or 88
93¾	ℓ	94
100	10	100

It may be remarked that those prices are retained from the circulation of Spanish coins in the United States, to which I beg to reply that if such prices and coins were not the most natural to the mind, and the most suitable for the market, they would not be retained.

Postage Stamps.—The following are the Post stamps of the United States.

1ct., 3ct., 10ct., 12ct., 24ct., 30ct., 90ct.

The very first glance at this series shows plainly that there is some confusion about it. The stamps of even post prices are not even in a dollar (except 1ct.) and four of them are not even in any coin. The simple and even numbers, most valuable in calculation, as 2, 4, 8 and

16, are of necessity omitted, because the decimal system does not admit the natural numbers. Let us now turn our attention to

Tonal Post Stamps.

Tonal Stamps.					American Cents.
4 cents	for	city post			= $1\frac{2}{15}$ cents.
8 cents	"	single letters			= $3\frac{1}{8}$ "
1 shilling	"	double letters			= $6\frac{1}{4}$ "
2 shillings	"	quadruple letters			= $12\frac{1}{2}$ "
4 shillings	"	8	"	"	= 25 "
8 shillings	"	10	"	"	= 50 "
1 dollar	"	30	"	"	= 1 dollar.

Here it will be found that the *tonal post stamp series* contains the even number most simple for calculation, and they are even both in post prices and in the *tonal* coins or dollar.

Division of the Year.—The new year ought to commence at Christmas, and the year divided into 10 (16 deci.) months, which would make about 17 (23 deci.) days per month.

Seasons.	Number of the month.	Number of days per month.	Names of the new months.	The first day of the new month to commence on	
Winter.	1	17	Anuary,	21 December.	New Year and Christmas.
	2	16*	Debrian,	13 January.	
Spring.	3	17	Timander,	4 February.	
	4	16	Gostus,	27 February.	
	5	17	Suvenary,	21 March.	Night and day of equal length.
	6	17	Bylian,	13 April.	
Summer.	7	17	Ratamber,	6 May.	
	8	17	Mesudius,	29 May.	
	5	17	Nictoary.	21 June.	Midsummer day, or St. John.
	9	17	Kolumbian.	14 July.	
Autumn.	ℰ	17	Husamber.	6 August.	
	℧	17	Vyctorious.	29 August.	
	ℰ	16	Lamboary.	21 September.	Night and day of equal length.
	ℭ	17	Polian.	13 October.	
Winter.	ℸ	17	Fylander.	5 November.	
	10	17	Tonborius.	28 November.	

*17 days in leap year.

There will be 16ℰ tonal days in a year, and 16ℭ in leap years.

The names of the *tonal months* are given so, that the first syllable expresses the number of the month in the year, and every four months have a similarity in sound, impressing the quarters of the year. The

new year and Christmas should be on the same day. There is no occasion for altering the days in the week, but when days are to be expressed by *tonal fractions* of the months or year, the number of days are nearly 80 per sant more than the fraction, for instance 6 days = 0·4 months or 0·04 years, 5 days = 0·6 months, 7 days = 0·8 months, 9 days = 0·09 years, 12 days = 0·01 years, &c., &c. The different Kalenders used in different countries, would by the *tonal system* at once fall into *one*. The old or Julian style is yet used in Russia and other countries, it is 12 days behind our new or Gregorian style. The Evangelistic year commences December 27, on the day of St. John; this style is also adopted in Freemasonry, where it is known as the Masonic year. The *tonal style* would become 7 days ahead of the Gregorian.

Measure of Heat.—The three different thermometrical scales causes a great deal of inconvenience in science and art. Although Fahrenheit's scale is generally employed in the United States, yet we have American Scientific books in which Celcius' scale is used exclusively. Celcius' decimal scale is the most convenient for calculation, but those degrees are too large for scientific purposes, for which we want the scale divided into more parts between the freezing and boiling points.

By the *Tonal System* it would become most natural to divide the thermometer scale into 10 and 100 (16 and 256 decimal) parts between the freezing and boiling points of fresh water.

Tonal System.		Old System.
Zero, or 0	=	+ 32 Fah. or 0 Celcius.
1 Temp. = 10 tempton	=	11¼ " " 6¼ "
1 Tempton	=	0·7 " " 0·4 "

A more philosophical division of the thermometer scale would be to start from the absolute zero, about 500° Fah., (Professor Rankine assumes the absolute zero at —461·2 Fah.) below the freezing point, or 2ℓ8 tonal.

(To be Continued.)

Preservation of Iron-plated and other Ships.

From the Journal of the Society of Arts, No. 560.

Sir:—I have read with much pleasure the interesting paper which has appeared in your *Journal* respecting the patent of Mr. Jean Pierre Jouvin, for preserving iron-plated and other vessels, and metallic articles from oxidation, and preventing ships' bottoms from fouling.

My object in addressing these few lines to you is not to discuss this important invention, but to lay before the members of the Society a few facts which I have observed during the last few years, in the course of some researches which Mr. Richard Johnson and I have made on this most interesting subject.

In the year 1858, Mr. Jonson and I took plates of iron, and covered one surface with $\frac{1}{20}$, $\frac{1}{40}$, $\frac{1}{80}$, and $\frac{1}{100}$ of its extent of zinc plate, which we tied close to the iron plates, and then immersed them in soft and

sea water. We examined these plates at the end of one, two, and three months, and finding that the zinc had exercised a very remarkable preservative effect upon the iron, we brought the matter under the notice of Mr. Robinson, shipbuilder, at Newcastle, who promised to institute a series of experiments in connexion with his iron ships, to ascertain whether the results we had obtained in my laboratory would be confirmed on a practical scale, but this gentleman soon after fell ill, and ultimately died. In the meantime it occurred to us that the most practical mode of applying zinc for the preservation of iron ships would be to use galvanized iron, and we therefore instituted a series of experiments to ascertain the extent to which protection would be thus afforded.

Plates of iron three inches square were attached with great care to pieces of oak of the same surface, and immersed in soft and sea water. Similar plates of galvanized iron were also similarly attached to pieces of oak and immersed in soft and sea water, and the following were the results observed after two months' immersion, viz: from January 3d to March 5th, 1862:—

		Loss by corrosion.
Pieces of wood and iron,	in distilled water,	1·230
		1·230
	in salt water,	2·400
		2·380
Pieces of wood and galvanized iron,	in distilled water,	0·100
		0·125
	in salt water,	0·095
		0·090

We were anxious to know whether a prolongation of the experiment would continue to show the same comparison, and we therefore again immersed the plates in distilled and sea water until May, 1863, when the iron plates were again removed from the pieces of oak, carefully washed and dried, and weighed.

		Loss by corrosion.
Pieces of wood and iron,	in distilled water,	1·700
		1·550
	in salt water,	4·320
		4·280
Pieces of wood and galvanized iron,	in distilled water,	0·500
		0·830
	in salt water.	0·780
		1·220

These results leave no doubt of the great protective power exercised by zinc against the corrosive action of water, and especially of sea-water upon iron plates. I therefore think that all iron used in shipbuilding should be galvanized, and as this operation is now performed with such facility and so little expense, I cannot see any commercial objection to its general adoption. There is a further argument in favor of this course, in the fact that it is not the loss of iron only that is in question, important as that is, but there is also the wood, which, especially in the case of oak, is rapidly deteriorated by the presence of oxide of iron, upon which the gallic and tannic acids of oak exercise a pow-

erful action, and thus cause the wood to enter into a state of rapid decay, or emaracausis, well known to shipbuilders.

Mr. Johnson and I also deemed it advisable to ascertain whether the zinc was liable to be removed from the surface of iron by intense friction, and to decide this point we made the following experiments:—

Large bolts, one foot long and half an inch in diameter, were driven into solid blocks of oak by a sledge hammer. The blocks were then opened and the bolts were found to be not in the slightest degree uncoated. Another series of experiments was made, consisting of driving screws of the same diameter as the bolts into solid blocks of oak, and the same satisfactory results were obtained.

I am, &c.,

F. Crace Calvert.

Manchester Royal Institution, Aug. 12, 1863.

Albumen from Fish Roe.

From the London Athenæum, July, 1863.

In consequence of a prize having been offered in France for the invention of a substitute for albumen prepared from hens' eggs, an albumen equal in quality and much cheaper has been discovered, which is made from fish roe.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, October 15, 1863.

John Agnew, Vice President, in the Chair.

Isaac B. Garrigues, Recording Secretary.

The minutes of the last meeting were read and approved.

Donations to the Library were received from the Royal Geographical Society, and the Society of Arts, London; the Natural History Society and L. A. Huguet-Latour, Montreal, Canada; Prof. A. D. Bache and the Department of Agriculture, Washington, D. C.; Prof. P. H. Vander Weyde, City of New York; the Legislature of Pennsylvania, Harrisburg, Penna.; Strickland Kneass, Esq., William A. Rolin, Esq., Philip Price, Esq., Prof. John C. Cresson, and the Select Council of the City of Philadelphia.

The Periodicals received in exchange for the Journal of the Institute were laid on the table.

The Treasurer's statement of the receipts and payments for the month of September was read.

The Board of Managers and Standing Committees reported their minutes.

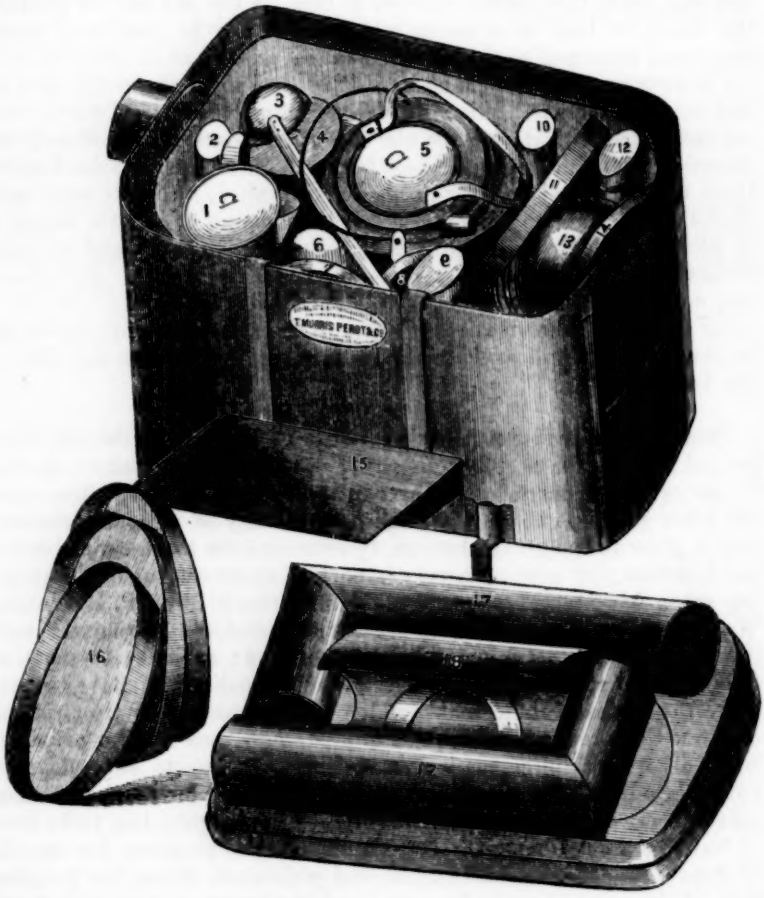
Candidates for membership in the Institute (4) were proposed, and those (7) proposed at the last meeting were duly elected.

Prof. A. L. Fleury exhibited a new device for protecting residences and warehouses from burglary by means of the common Street Gas, the invention of Dr. P. H. Vander Weyde, Prof. of Chemistry at the New York Medical College and the Cooper Union. This small and economical contrivance can be applied in all places where gas is used. It is placed out of reach of the burglars, so that if the gas is once turned on it continues its loud shrill whistling till the inmates of the house or the police turn off the gas. When desired to be arranged at a great distance from the place to be protected, and no objection exists against the expense of an electric battery, it may be connected by a small electro-magnetic arrangement, so that the opening of a door or window, or the putting of a key to a lock, produces the contact and sends the electric current to turn on the gas and to produce the alarm as loud as a steam whistle. It can be used as a night lamp, and arranged so that it will awaken persons at an early hour in the morning; it will continue its shrill sound until the party gets up and turns off the gas. When the doors of a whole block of warehouses are connected with it, and the alarm is placed outside, it will call the attention of the police in the neghborhood for several blocks distant. Once well arranged it never needs looking after, as is the case with clocks, which have to be wound up, or the keeping of electric batteries in working order, which requires some knowledge, care, and expense for acids and zinc. It can also be used as a fog signal. It is cheap and convenient, easily managed, and sufficiently loud to be heard at a great distance. Information relating to the sale of patent rights can be obtained by application to the inventor at the office in the Hall of the Institute.

Prof. Fleury read the following notice of Dr. Vander Weyde's improved Process for Stereotyping. The saving of labor and material in the various departments of arts in these times of war, when manual labor has become very expensive, is worthy of all our attention, and it gives to me great pleasure to communicate to the members of the Institute this evening a very important improvement in the printing art, a new stereotype process, the invention of Prof. P. H. Vander Weyde. Most of the members present are no doubt acquainted with the process of stereotyping as is now practised; suffice it to say that publishers of stereotyped and electrotyped book-works have to preserve the plates of their books, which when worn out by the printing of a few thousand copies require to be re-cast, and all the primitive work of setting-up, correcting, moulding, &c., has to be gone over again, besides all the plates in type metal (having for a common sized octavo book of 400 pages about 1000 lbs. in weight), has to be kept on hand as a dead capital. Dr. Vander Weyde prepares his moulds of paper, rendered incombustible, and publishers using his process, may, if they choose, only keep on hand the paper moulds and metal enough to cast 16 or 32 pages, the same metal being used over and over again for the necessary sheets as they are printed. It can easily be seen that considerable time is saved, as during the com-

position of the work, every form may be distributed as soon as the mould is made, without waiting for the result of the casting. The Dr. has his process in successful operation in two publications, one is an Instruction book for the Piano, the other a Magazine for Mathematics and Physics, and he is ever willing to show the process in all its details. Not having received the expected samples in time for our present meeting, I shall have the pleasure to explain and demonstrate the process practically at our next meeting.

Mr. Howson, Chairman of the Committee on Meetings, exhibited T. Morris Perot & Co.'s improved Army Mess Chest. The case is made of convenient size for handling and transportation, and contains



a sheet iron stove, illustrated in the cut. Within the stove is a case, which, when removed and placed in an inverted position on the top of the stove, forms an oven. The top of the stove can be removed, in or-

der to take out the inner casing; and in the latter are packed the following articles:—one coffee pot, six cups packed inside of coffee pot, one salt box, dipper and ladle, one tea pot, one mess pot, one saucepan packed in the mess pot, one tea kettle packed in the saucepan and mess pot, six tin tumblers, lid of mess pot, one grater, twelve knives and forks in case, one pepper box, one frying pan, one gridiron packed inside of frying pan, with the top against the pan, six iron tablespoons, tinned, and six iron teaspoons, tinned, in case; six small basins, two wash-hand basins, six plates, (plates to be placed in the small basins, and these in the large ones); lid of saucepan; iron rack, to be placed on the lid of the boiler when closed; one tray, to be placed inside of tin dishes; two tin dishes, these with the tray to be placed bottom upwards, over the tea kettle and coffee pot; stove pipe on top of stove; draft regulator, to be placed between the pipes on stove.

The chest contains several large canisters, marked for tea, coffee, sugar, and butter, and a tray containing six Britannia mugs.

A somewhat similar chest, without the stove, made by the same firm, was also exhibited. In this are two tripods, with a connecting rod, on which articles may be hung to cook over the fire. Either of the chests must prove invaluable to the medical department, for which they are intended, although they would answer equally well for officers, emigrants, and others.

Mr. Howson exhibited J. G. Lefler's improved Water Filter. In the upperend of an upright tube is a detachable bucket or case, with a perforated bottom, and filled with sand, gravel, or any other suitable filtering material. The inlet pipe is tangential to the case, and is attached to the same about midway between the top and bottom; and at the lower end of the case is an outlet cock. As the water enters the case through the inlet pipe, the heavier particles of dirt fall to the bottom, the lighter particles are carried upward, and if not arrested by the perforated bottom of the bucket, they lodge in the filtering material contained therein, while the water passes out at the top of the case in a purified state. The rotary motion given to the current of water, as it passes from the tangenital tube and strikes the inner side of the case, cleanses the latter of any impurities which may adhere to the sides.

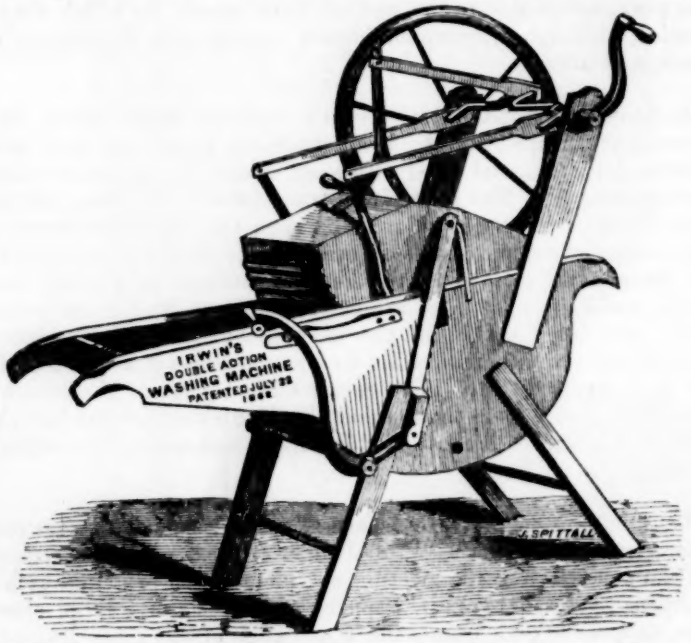
Mr. Howson explained, by means of a large model, the optical illusion generally known as Prof. Pepper's Ghost. Mr. H. remarked that the model before the meeting was identical in principle with the apparatus patented by Prof. Pepper It consists of a large sheet of glass, supported on a frame, the upper edge of the glass leaning toward the audience. On an inclined platform below the lower edge, and in front of the glass, are placed the objects to be reflected by the glass, a bright light being thrown on these objects by means of a reflector. Several plaster casts, and other objects, were placed on the platform, and the reflection appeared quite as distinct in every respect

as the originals, although apparently suspended in mid air, and occupying an indefinite position in respect to the distance from the spectators.

Lieutenant Colonel F. D. Hart's Improved Shell was exhibited by the inventor. The shell is elongated, of cast iron, the body being surrounded by vertical strips firmly secured to the same, but which when the shell explodes, readily separate, thus insuring a more perfect division of the parts, and a consequent more destructive effect.

Mr. Shaw gave the details of a new Locomotive Engine, which has been built by James Milholland, Esq., for the Reading Railroad Company. This engine, which weighs over 100,000 lbs., it is supposed will be able to push four hundred cars at one time on a level.

Irwin & Guest's patented Clothes Washing Machine was exhibited by Mr. Washington Jones. (This machine is shown in the accompanying cut). The clothes are placed in a semi-cylindrical tub, which is contained within the exterior case, and the inner surface of which is ribbed, and on to the clothes thus placed, is lowered a semi-cylin-



drical rubber, ribbed on the outside; a vibratory motion in opposite directions is given to both the tub and rubbers by turning the crank shaft, so that the clothes will be rubbed between the two ribbed surfaces and thoroughly cleansed. The invention also consists of the device, illustrated, whereby the upper rubber may be readily raised and lowered.

Mr. John W. Nystrom submitted models and diagrams of ships, and made the following remarks:

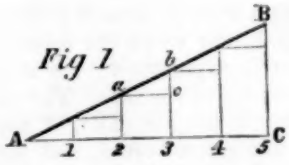
I have invited to the meeting this evening some shipbuilders and engineers, with a view of discussing with them a new system of constructing ships, called the Parabolic construction, partly described in the *Journal of the Franklin Institute.* I hope my friends, shipbuilders and engineers, will discuss and make remarks on the subject the same as if we met in a private parlor. I will not lead you, as you might expect, into complicated calculations, but confine myself to simple reasoning, which you can all understand. Most practical men do not like to read books, and they particularly object to study new systems. I have, therefore, chosen this course to impress upon you the great importance of the Parabolic construction of ships; the more I study into it, the more am I convinced that it is the true principle of naval architecture; it ought to be adopted in every school of shipbuilding.

Shipbuilding and steam engineering are arts in which we take the greatest pride; still there is not, to my knowledge, a single school or institution in the country where we can learn to build a steamboat. I have not invited you here to teach you how to construct a ship, for I shall prove that you knew how before you saw or heard of me.

In my discussion I will have frequent use of the term *exponent*—a term not generally understood. In many works on shipbuilding the term exponent is misapplied. Mr. Griffith calls exponent the per centage the displacement of a vessel occupies in the parallelopipedon of the same length, breadth, and depth, which ought to be called co-efficient, because the displacement is the co-efficiency of the parallelopipedon; exponent and co-efficient are as different as night and day.

Suppose the numbers in the column (a) to represent ordinates of the line (A B, fig. 1). Differentiate the ordinates, subtract one from the

	a	d^1
1	125	
		125
2	250	
		125
3	375	
		125
4	500	
		125
5	625	



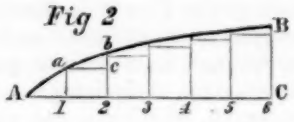
other repeatedly, and place the difference in the column (d), in this case is a constant number, 125, which proves that the line is straight, or of the first order, or its exponent is 1. Draw $a\,c$ parallel with the base A C, and $c\,b$ is the first difference, which we see is constant for all ordinates.

Again, let the numbers in the column (a) represent ordinates of a line (A B, fig. 2). Differentiate the ordinates as before, and you will find that the first differences d^1 are not constant numbers, but can again be differentiated to d^2, which we find is constant; the line A B

has therefore two differentials, or it is of the second order, or its exponent is 2.

	a	d^1	d^2
1	2345	2031	
2	4376		312
		1719	
3	6094		313
		1406	
4	7500		313
		1093	
5	8593		312
		783	
6	9376		

Fig 2



The first differential, d^1, represents ordinates for a line of the first order. The second differential should be $d^2 = 312{\cdot}5$, but as the ordinates a are not carried out to sufficient correctness with decimals, the second differential appears 312 and 313.

One more example will be sufficient to illustrate what is meant by lines of different order or exponent.

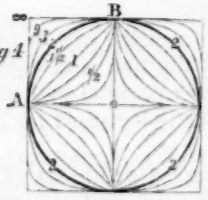
Differentiate according to the scheme.

	a	d^1	d^2	d^3	d^4
1	4138	2698			
			1060		
2	6836	1638		323	
			737		60
3	8474	901		263	
			474		57
4	9375	427		206	
			268		60
5	9802	159		146	
			122		59
6	9961	37		87	
			35		
7	9998	2			
8	10000				

Fig 3

Here we find that the fourth differential is a constant number, or a line A 4 B (fig. 3), for which the column a are ordinates, is of the fourth order, or of the exponent 4; the number of differentials shows their order or exponent of the line. The numbers in column d^1 may represent ordinates for the line A 3 B of the third order, column d^2 for the line A 2 B of the second order, and the column d^3, which has only one differential, for the straight line A 1 B of the first order. The first differential is the apparent distance between the frames in the body plan of a ship's drawing. All the curved lines in the conic sections known as *circle*, *ellipse*, *parabola*, and *hyperbola*, are lines of the second order; but if we change the exponent, those lines will no more be conic sections, as I shall here endeavor to illustrate. We have here a round circle (fig. 4), with the exponent 2; if we increase the exponent say to 3, the circle will not be round, but

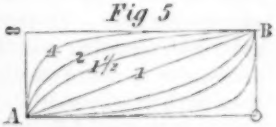
Fig 4



of this form (A 3 B), and the more we increase the exponent the nearer will the circle be a square, which it becomes when the exponent is ∞. If we diminish the exponent from 2 to 1, the circle will then become a square, inscribed in the round circle; when the exponent is ½, it will be an inverted circle, as shown in the figure; and when the exponent is 0, the circle will be a cross.

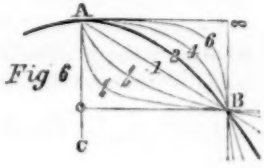
The law is precisely the same for an ellipse. Suppose A 0 to be the centre line of a vessel, A the stern, and 0 the dead-flat. It is desired to make an elliptic stern; the true ellipse from the conic section is rather sharp, but by increasing the exponent we can make it as full as we please, until it become perfectly square. The exponent 4, which is drawn on the figure, makes a good-looking stern.

Fig 5



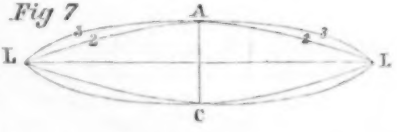
Let A C, fig. 6, represent the axis of a parabola, and the line A 2 B a conic parabola of the second order; A 4 B fourth order; A ∞ B an indefinite order, when the parabola becomes square; A 1 C the first order, or a straight line; and A ½ C a parabola of the second root or ½ order; and lastly, when the exponent is 0, the parabola becomes A 0 B, or square.

Fig 6



Let L L, fig. 7, represent the centre line of a vessel, and A C the dead-flat 𝒳; then A 2 L a conic parabola with the exponent 2, will be the sharpest form of load water-line a vessel can have within the length L L and breadth A C, for the least possible resistance.

Fig 7



By altering the exponent of the line we are able to form any fulness or sharpness we please, as illustrated by fig. 7.

Hollow lines are formed by reversing the parabola, and it is found theoretically that the reverse should commence at one-third of half the breadth from the centre line, as described in the *Journal of the Franklin Institute*, and in my treatise on Parabolic Shipbuilding.

I have here a drawing of water-lines of different sharpness and exponents (Plate*), of which this first one is the sharpest form, constructed with the exponent 2. The centre line is divided as you see, from the dead-flat 𝒳 to the stern and bow, into eight equal parts, and the eight ordinates calculated for twenty different exponents, contained in tables in my Pocket-Book on Engineering.

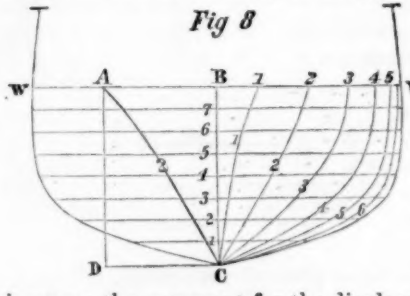
The frames in a vessel should also be parabolas of different order, with the axis in the load water-line W L, as shown on the drawing. By altering the exponent we can give the frames any fulness we please, from a flat bottom to any desired rise. The area of the immersed frame is found by multiplying together the breadth, depth, and the co-efficient for the exponent; this co-efficient is found in next

* This Plate will appear in the December number of this Journal.

to the last column in the tables. Now we come to the most important part of the discussion, namely, how to form the displacement so as to present the least possible resistance when forced through water. The immersed area of each frame should increase or diminish in a certain series, found theoretically to be that the square root of the sections should be ordinates in a parabola, the exponent of which depends on the desired fulness of the displacement. When the ordinate cross sections are so proportioned, the displacement will present the least possible resistance. In my Pocket Book and also in my treatise on Parabolic Shipbuilding will be found a table calculated with twenty exponents, for areas of the immersed ordinate cross sections. When this area with the breadth A B and the depth B C are known, we can find the exponent and form of the frame by the following process: Subtract the given area A 2 C B (fig. 8) from the rectangle A B C D, and the remainder, A 2 C D, divided in A 2 C B, gives the exponent for the form of the frame A 2 C.

I have here a model of the displacement of a vessel constructed wholly by the parabolic method; every cross section or frame is a parabola; the frame drawing or body plan is laid down direct from calculation without reference to water-lines or diagonals and without exercise of taste. You may remark that there is no taste about it, and if such is the case, I beg you not to blame the parabolic system, for the error is then that I have not selected the exponent which pleases you; keeping the same water-line and midship section, and only increase the exponent for the displacment, it becomes fuller in the bow as you may desire. This table contains the ordinates for the construction.

Fig 8



Abaft.			Frames.	Forward.		
n	$n=4$	$n'=5$		$n''=3$	$n=3$	n
0·441	2962	4871	1	9060	2284	0·658
0·817	5063	7627	2	2785	5063	1·22
1·40	7143	9046	3	4761	7143	2·00
2·23	8537	9687	4	6381	8537	2·96
3·25	9383	9926	5	7465	9383	3·90
4·28	9817	9998	6	8070	9817	4·61
4·84	9977	9999	7	8285	9977	4 90
5·00	10000	10000	8	8333	10000	5·00

Exponent for the Frames. — Exponent for the Frames.

Here Mr. Nystrom explained the models and their bearing on the parabolic construction.

When the exponent for the frame is thus found, it is a mere chance if it falls in with one of the forty exponents calculated in the tables, for which it has been found necessary to construct a diagram that will give the proportional ordinates for any exponent to a certain limit; this diagram is constructed in the following manner (Plate*): A B is divided in an arithmethical progression and represents the ordinates, B C in logarithmic progression, to represent exponents from 0 to 10. On the exponent line 2, 2, set off from the base B C the ordinates for the exponent 2, table I., and repeat the same for the rest of the exponents in the tables; then join the ordinates of the same number by lines through the different exponents, and a diagram of this form is obtained. This applied to the preceding table and fig. 8, the exponent for the 2d frame in the stern is 0·8175, for which we find on the diagram the co-efficient for the ordinates as follows: 1st = 0·102, 2d = 0·206, 3d = 0·315, 4th = 0·435, 5th = 0·550, 6th = 0·678, 7th = 0·815 and the 8th is the line A B or ordinate for the water-line, fig. 8, which multiplied by the co-efficients gives the corresponding ordinates for the frame. In practice the multiplication is performed by a scale, and thus the form of every frame can be laid down without reference to water-lines, or calculation.

The Navy Department often gives the dimensions, length, breadth, and draft of water of a vessel, and that the displacement shall occupy a certain per centage of the parallelopipedon, as a problem for the shipbuilder. Except in the parabolic construction, there is no established rule by which to lay down direct a given displacement of a vessel, but the constructor goes to work and makes an approximate drawing, and perhaps a model from which the displacement is calculated; if found to be too large or too small, the drawing and model is altered perhaps several times before the desired result is obtained, and so he feels himself ahead like a blind man. In the parabolic construction we go to work with the greatest certainty of attaining the desired result.

The following is part of a table copied from my Pocket Book, to show how simple such a problem can be solved; it contains the per centage of displacement for different exponents.

Exponents.		Exponents for Displacement.			
		2	3	4	6
Dead Flat ℵ	2	35·6	43	47·4	52·8
	3	40	48	53	59
	4	42·7	51·4	57	63·5
	6	45·8	55	61	68

Required the form of a vessel with a displacement of 55 per cent. of the parallelopipedon? In the table we find that 55 corresponds with the exponent 6 for the dead-flat ℵ, and 3 for the displacement, which will give the proper form of the vessel.

* This Plate will appear in the next number.